18 Access Spacing

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Track 2- Technical

COMPARISON OF DELAY AND ACCIDENTS ON THREE ROADWAY ACCESS DESIGNS IN SPRINGFIELD

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ABSTRACT

A comparison was made of three urban arterial roadways in Springfield, Missouri, each having similar lengths, posted speed limits, volumes, and abutting land uses but different levels of access control. The three segments were close to each other. The street with the highest level of access management (a non-traversable median and a much greater access spacing) was found to have both a lower crash rate and less delay than the other two roadway sections with a center turn lane. A comparison of the two center turn lane roadways found that an increase in driveway spacing did not produce faster travel times or a lower crash rate.

key words: access management, crashes, geometric design, medians

COMPARISON OF DELAY AND ACCIDENTS ON THREE ROADWAY ACCESS DESIGNS IN SPRINGFIELD

by J. L. Gattis, Ph.D., P.E., and David Hutchison, P.E.

INTRODUCTION

Springfield is the quintessential American city name. One particular Springfield gives researchers an opportunity to evaluate the service and safety provided to the public by three urban arterial roadways, each having a different design and abutting land use pattern.

Springfield, located in southwest Missouri, is a city of about 150,000. It is the largest city between Tulsa and St. Louis, and between Memphis and Kansas City. The city has fairly level terrain, and the square-mile street grid common to many American cities laid out after the enactment of the Northwest Ordinances. In this study, the crash rates, travel times, and other attributes of three urban street segments were compared; two of the segments were parts of the same arterial roadway and the third segment was on a perpendicular, intersecting arterial.

DESCRIPTION OF THE THREE SEGMENTS

The roadways included in this study are shown in Figure 1, and photographs of each segment are shown in Figure 2. Two of the three roadway sections that were compared are segments of Glenstone Avenue, a north-south oriented roadway. The two segments were termed Glenstone-north and Glenstone-south. The third segment that was compared is a part of east-west oriented Battlefield Road. The three segments have 40 mph posted speed limits, with the exception that Glenstone south of Primrose has a 45 mph posted limit.

The segments were selected to contrast the three different types or levels of access control found along them. Glenstone-north, with lenient driveway spacing, has little access management. Glenstone-south has a high degree of access management. Battlefield, which has raised medians within 60 m (200 ft) of signalized intersections, is abutted by tracts exhibiting a newer style of land development which results in a driveway frequency of roughly half that of Glenstone-north. All three segments are similar in that they are lined by mostly commercial development along each side. Much of the traffic that traverses Glenstone-north also travels on Glenstone-south. The short roadway section separating Glenstone-north from Glenstone-south was eliminated from this study because it is fronted on one side by a large cemetery. The lengths of all three segments are similar, ranging from 2.44 to 2.58 km (1.51 to 1.61 mi).

Traffic Patterns and Characteristics

Glenstone-north and Glenstone-south are numbered as US 65 Business Route. Years ago, Glenstone was the primary north-south highway route through the area, but now regional traffic is more likely to be found on US 65, a freeway parallel to and about 3 km (2 miles) east of Glenstone. Still, Glenstone is a primary arterial for traffic within Springfield.

Battlefield intersects Glenstone-south. Battlefield is a primary arterial for city traffic, but regional traffic uses parallel US 60 freeway about 2 km (1.2 mi) to the south.

Abutting Land Use

Glenstone-north is lined with what by today's standards are relatively small- to medium-sized commercial tracts, with a scattering of highway-oriented business harkening to its past. Some of the tracts have been redeveloped with newer commercial buildings, but the majority appear to be many decades old. From reviewing video tapes of the abutting land uses, it was estimated that there were 21 fast food and restaurant sites, 9 gasoline service stations, 22 shopping centers (either strip or neighborhood) , 2 motels, and 32 bank/office/professional uses.

Glenstone-south is fronted with larger commercial tracts, including Battlefield Mall, the region's major shopping center. Nationally-known retailers and "big box" stores have a high visibility in this corridor. There were 3 freestanding fast food and restaurant sites, 0 gasoline service stations, 13 shopping centers (ranging from strip to regional), 3 motels, and 2 bank/office/professional uses. The majority of the development appears to be less than thirty years old.

Battlefield Road is abutted by a number of relatively large commercial tracts, with development styles typical of the late twentieth century, similar to those of Glenstone-south. It also passes along the side of Battlefield Mall. However, there are some smaller commercial tracts along this segment. There were 10 identifiable fast food and restaurant sites, 2 gasoline service stations, 15 shopping centers (ranging from strip to regional), 2 apartment complexes, and 14 bank/office/professional uses. There is one section of undeveloped land along the south side of Battlefield Road. Even though Battlefield Road is like Glenstone-north in that both have a flush median, center turn lane design, tracts along Battlefield are much deeper than those along Glenstone-north. The greater tract depth means a greater total land area funneling traffic to Battlefield, which potentially translates into a greater number of trips generated per length of street frontage. This means more turning movements into and out of parcels abutting Battlefield than parcels along Glenstone-north .

Volumes

Table 1 contains a summary description of the three segments and their volumes. City of

Springfield counts show that volumes on the three segments range from about 29,000 to 38,000 vehicles per day.

On all three segments, the majority of the intersections with cross streets were signalized. Approach volumes on these streets ranged from less than 2,000 to 18,000 vehicles per day. The sums of the approach volumes on all of the signalized intersection approaches were as follows:

Glenstone-north 70,200 Glenstone-south 66,100 Battlefield 97,900.

Intersections and Signalization

Along the Glenstone-north segment, six of the ten street intersections are signalized. All six Glenstone-south street intersections are signalized. Battlefield has seven signalized intersections and one unsignalized T-intersection.

Although the numbers of public street and signalized intersections along all three segments are similar, there is a striking difference in driveway frequency among the three sections. Table 2 shows that Glenstone-south has less than one driveway per km, Battlefield has about 24 driveways/km, and Glenstone-north has 43 driveways/km. All of these driveway frequencies are counting driveways on both sides, per length of roadway.

Geometric Characteristics

All three sections of urban arterial studied have four through lanes and relatively level grades. Battlefield and Glenstone-north are straight, while the southern part of Glenstone-south includes a large-radius horizontal curve.

Both Glenstone-north and Battlefield Road have curbs and gutters, and flush medians occupied by a center two-way left turn lane. Along Battlefield, the median is raised on the approaches to the signalized intersections; this has the effect of preserving the left turn area only for vehicles turning left at the intersection, and denying its use for any Battlefield Road driver intending to turn left into a driveway immediately upstream or downstream of the signalized intersection.

Glenstone-south has a depressed, non-traversable median along its entire length except at the northmost intersection, where the median transitions into a center turn lane. Left-turn and some right turn lanes exist at intersections. Instead of curbs, a narrow shoulder is present. There are privately-owned frontage roads along one-quarter of the frontage. Two of these frontage roads intersect a cross street (at Erie and at Peele) within 30 m (100 ft) of the Glenstone main lanes; two other intersections are well set back from the Glenstone-south main lanes. Including openings at either end of the segment, there are 6 median openings over a length of 2.58 km (1.61 mi), for an average spacing of 0.5 km (0.3

mi.).

Double-lane left turn lanes are present at some of the Glenstone-south and Battlefield intersections. All left turn lanes along Glenstone-north are single lane.

SERVICE ATTRIBUTES OF THE THREE SEGMENTS

Although one can identify a number of attributes that measure how well or how poorly a roadway is serving the public, two factors whose impacts are obvious and directly felt by the traveling public are travel time and safety. Travel speed is closely related to travel time over a roadway segment. To assess the performance of the three segments, travel speed and crash rate data were analyzed.

Travel Speeds

City of Springfield travel time data was employed to evaluate the quality of flow on each of the three segments. The Springfield Public Works Department collected this moving vehicle data in 1997, 1998, and 1999 to evaluate and improve signal timing along the segments. The data included trips made during all daylight periods, both peak and off-peak. The driver collecting the data attempts to stay with the flow of traffic; runs are made in both outside and inside lanes. The average travel times were calculated from data sets comprised of anywhere from 30 to 67 different runs made on the different segments in one direction. The average speeds shown in Table 3 were computed from average travel times over the segment length.

Average speed on Glenstone-north was about 32 km/h (20 mph). Interestingly, on the Glenstone segment to the south, average speed jumped to about 51 km/h (32 mph). Speed on Battlefield averaged 28 km/h (17 mph).

Travel speed on the three streets seems to be controlled more by signal spacing and timing than by access density. Along Glenstone-north and Battlefield, turning movement friction does have some effect. During low volume periods, one can travel these roadways with very few stops. During high volume periods, a vehicle may encounter the rear of the queue from a signal ahead that has already turned green.

Average travel speed may have been somewhat affected by the green splits along each of the arterials. Signals along all three streets are timed to provide progression. A review of the signal timing plans showed that the daily average percent green was slightly higher on Glenstone that on Battlefield. The least percent green on Glenstone was 33% at the Sunshine intersection, while the lowest percent green on Battlefield was 24% at the National intersection.

Crash Histories

The city of Springfield furnished four years of both intersection and midblock summary crash data for the three segments. The intersection crash data included accidents that occurred within 30 m (100 ft) of any of the approaches to the intersection. Crashes on the private frontage roads along some parts of Glenstone-south are not entered into the crash data base. However, crashes on the west-side frontage road intersection at Erie that is close to the main lanes are included with the Erie and Glenstone-south crash totals.

Glenstone-south had the lowest crash rate and Battlefield had the highest (see Table 4). The overall crash rate was 25% higher on Glenstone-north and 71% higher on Battlefield. The injury-plus-fatality crash rate was 28% higher on Glenstone-north and 60% higher on Battlefield. When considering only what were coded as mid-block injury and fatal crashes, Glenstone-north and Battlefield had rates of 2.5 times or more that of Glenstone-south.

All three street segments had similar signalized intersection crash rates. Taking the total number of intersection crashes and dividing it by the combined approach volumes at all signalized intersections, Glenstone-north had 1.5 crashes per million entering vehicles (MEV), Glenstone-south had 1.7 per MEV, and Battlefield had 1.9 crashes/MEV. The combined injury-plus-fatal crash rates were also similar, ranging from 0.42 to 0.48 per MEV.

A comparison of the types of crashes that occurred (see Table 5) is insightful. Considering only mid-block crashes, Glenstone-north and Battlefield traits were much different that those on Glenstone-south. On the first two, about half of crashes were categorized as “rear-end” or “following-too-close”, and a quarter to a third were “angle” crashes. On the other hand, over 80% of mid-block crashes on Glenstone-south were rear-end or following-too-close, with angle crashes being almost non-existent. The percentages of “sideswipe” crashes on all three segments ranged from 9% to 13%.

A majority of intersection crashes on all three segments fell into the rear-end or following-too-close categories. Battlefield exhibited a proportion of angle crashes that was quite a bit higher than that of the other two segments. The percentage of sideswipes on Glenstone-north was almost double that of Glenstone-south.

COMPARISON WITH PREVIOUS STUDY

A somewhat similar analyses had previously been performed *(1)* on three arterial roadways in Muskogee, Oklahoma, a city with a population of about 40,000. In this study, each of the three roadway segments had a non-traversable median, but the frequency of access varied greatly. Segment A had 61.4 access points per km, Segment B had 7.8 points per km, and Segment C had 3.6 per km. Segment B had frontage road in close proximity to the main lanes for much of its length. Volumes on the three segments ranged from the low- to the mid-20 thousands per day.

Average travel times on Segments B and C were much less than those on Segment A. The Segment B crash rate (3.45 per 10^6 veh-km) was similar to that of Segment A (3.52 per 10^6 veh-km) , but Segment C had a crash rate (1.99 per 10^6 veh-km) that was about 40% less than the rate of the other two segments. The injury rate for Segment C was about half that of the other two segments. Segment C had a slightly greater proportion of rear-end crashes and a smaller proportion of angle crashes than did the other two segments.

OBSERVATIONS AND CLOSING

The lengths, nature of traffic, and type of abutting land development were similar for the three segments that were evaluated. The posted speed limit on all three was 40 mph, except for a small part of Glenstone-south, which was posted for 45 mph. Daily volumes ranged from 28,900 to 38,300. The degree of access management and the driveway spacing varied significantly. The comparison of travel times and crash histories on the three urban arterial segments led to the following observations.

- The average travel speed calculated from dozens of trips on these three segments was over 50% higher on Glenstone-south (the roadway with highly-managed access) than on the other two sections having much less management of access.
- Even though the average travel speed was much higher, Glenstone-south, the urban arterial segment having the high level of access management, had a lower crash rate than did the other two nearby arterial segments with little access management. The much lower mid-block crash rate on Glenstone-south seemed to reflect the improved safety performance of the access-managed roadway over the other two non-access managed roadways. The number of signalized intersections and the signalized intersection crash rates for all three segments were similar.
- Although Glenstone-north had a much higher frequency of intersecting driveways than Battlefield Road, Battlefield exhibited lower average speed and a higher crash rate. Comparing these two five-lane designs, an increase in driveway spacing from 39 m (130 ft) to 66 m (220 ft) on one side did not produce any observable corresponding decrease in the crash rate or improvement in travel speed. It should be noted that the higher cross street volumes and smaller green splits on Battlefield Road may contribute to the poorer performance of this street. Also, from the greater depth of the commercial properties along Battlefield, one could infer a higher trip generation rate per amount of street frontage and larger driveway volumes than those along Glenstone-north.
- Compared with the three segments previously analyzed in smaller Muskogee, Oklahoma, volumes on the three Springfield streets were roughly 40% higher. The crash rate on the safest Springfield

segment, the one with the non-traversable median, was about 2 to 3 times higher than the rates on the three Muskogee segments (each of which had a non-traversable median). The intensity of the abutting land uses and the resulting amount of traffic generated from driveways and side streets may be higher in Springfield than in Muskogee. Similar to the Muskogee study, the Springfield street with the highest level of access control had a smaller proportion of angle crashes than did the other two segments.

Typical running speeds on urban arterials of the type studied in Springfield often range from 35 to 45 mph. The average travel speed for the access managed arterial was slightly over 50 km/h (30 mph) and the other two were around 30 km/h (20 mph); none of these speeds are excessive. Therefore, one could hypothesize the better performance of the access managed arterial was not due to excessive speed but rather due to the elimination of causes of delay, such as slowing down for vehicles turning off of or into the through street from driveways.

The three segments of roadway investigated were chosen because they were in the same section of the city of Springfield, they were all lined by commercial development, and two of the three were almost end-to-end. A study of the four year crash rates and of the travel time measurements for all three segments revealed that the access-managed urban arterial provided improved safety with less delay. In this study environment, the four-lane urban arterial with the non-traversable median outperformed the two five-lane roadways with the continuous center two-way turn lane. A previous study *(1)* of three segments in a smaller city, Muskogee, Oklahoma, found that the urban arterial segment with the highest degree of access management had both a higher travel speed and much lower crash rate that a raised-median segment having segment frequent driveways and cross streets, and had a lower crash rate than a segment with a somewhat greater intersection frequency. These studies raise a question: does introducing a low level of access management create any measurable added safety or reduction in delay? The findings from these few cases suggest the need to identify what degree or level of access management is required to consistently produce benefits of greater safety and less delay that those of ordinary urban arterials.

ACKNOWLEDGEMENT

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TABLE 1 Description of the Three Segments

Segment	Description	Length	Daily Volume (rounded)	Volume on Signalized Cross Streets
Glenstone-north	Little access management; continuous center left turn lane; frequent street and driveway intersections; abutted by many smaller commercial tracts	2.44 km (1.51 mi)	38,300	70,200
Glenstone - south	High level of access management; depressed center median, few median crossings; very few intersections; some continuous frontage roads; abutted by large commercial tracts	2.58 km (1.61 mi)	31,500	66,100
Battlefield	Some but not much access management; continuous center left turn lane with raised median at intersections; fewer intersections and driveways; abutted by a mixture of large and smaller commercial tracts.	2.51 km (1.57 mi)	28,900	97,900

Note: volumes in vehicles per day (vpd); frontage road volumes not included

TABLE 2 Main lane intersection characteristics

	Glenstone - north		Glenstone - south		Battlefield	
	#	per km	#	per km	#	per km
Signalized intersections	6	2.0	6	1.9	7	2.4
Median openings, total	na		6	1.9	na	
For streets			6	1.9		
For driveways			0	0		
Intersections, total	114	46.3	8	2.7	69	27.1
Streets	10	3.7	6	1.9	8	2.8
Driveways	104	42.6	2	0.8	61	24.3

Notes: Driveway intersections with frontage roads not included. Since signalized intersections were at both ends of all segments, spacing was calculated at one less than number of signalized intersections.

TABLE 3 -- Travel Speed

	Glenstone - north NB	Glenstone - north SB	Glenstone - south NB	Glenstone - south SB	Battlefield EB	Battlefield WB
Average - km/h	32.2	31.6	53.5	50.0	28.7	27.2
mph	20.0	19.7	33.3	31.1	18.0	17.0

TABLE 4 Crash Summary

	Glenstone - north	Glenstone - south	Battlefield
Total number of crashes	1159	813	1246
Non-intersection	463	163	417
Intersection	696	650	829
Proportion of non-intersection	39.9%	20.0%	33.5%
Proportion of intersection	60.1%	80.0%	66.5%
Severity			
Number of injuries	552	379	553
Number of injury crashes	342	234	335
Non-intersection	147	65	122
Intersection	195	169	213
Proportion of injury to all crashes	29.5%	28.8%	26.9%
Number of fatal crashes	2	0	0
Rates			
Crashes per million vehicle km (mvkm)	8.5	6.8	11.7
Number of injuries + fatalities per mvkm	4.1	3.2	5.2
Number of injury + fatal crashes per mvkm	2.5	2.0	3.1
Midblock Rates			
Crashes per million vehicle km (mvkm)	3.4	1.4	3.9
Number of injuries + fatalities per mvkm	1.1	0.5	1.1
Intersection Rates			
Crashes per million entering vehicles(MEV)	1.5	1.7	1.9
Number of injuries + fatalities per MEV	0.42	0.45	0.48

NOTE: Crashes totaled from 1995, 1996, 1997, 1998. Intersection crashes include crashes on intersecting streets.

TABLE 5 Crash Types

	Glenstone - north	Glenstone - south	Battlefield
NON-INTERSECTION			
Angle	123	2	139
Backing	3	1	3
Rear end/Following too close	261	135	207
Sideswipe	61	15	54
Other	15	10	14
TOTAL	463	163	417
INTERSECTION			
Angle	111	113	203
Backing	12	4	9
Rear end/Following too close	468	463	516
Sideswipe	80	41	70
Other	23	29	31
TOTAL	694	650	829

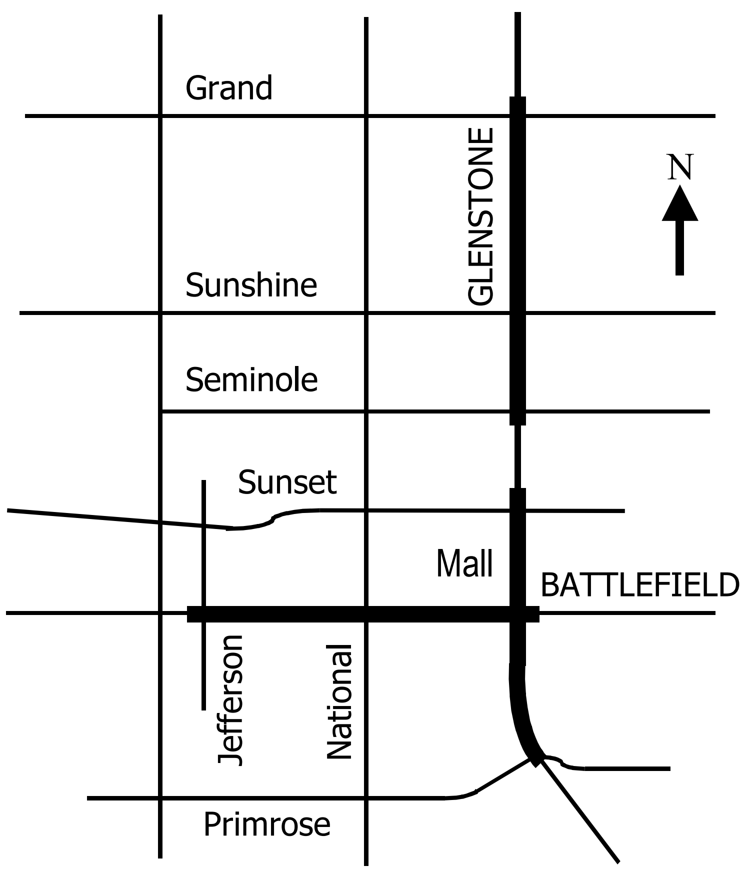

FIGURE 1 Schematic drawing of the three segments

COMPARISON OF DELAY AND ACCIDENTS ON THREE ROADWAY ACCESS DESIGNS IN SPRINGFIELD

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Introduction

- SPRINGFIELD, MO
  - POPULATION ~ 150,000
  - FAIRLY LEVEL TERRAIN
  - MILE-SQUARE GRID FOR ARTERIAL STREETS

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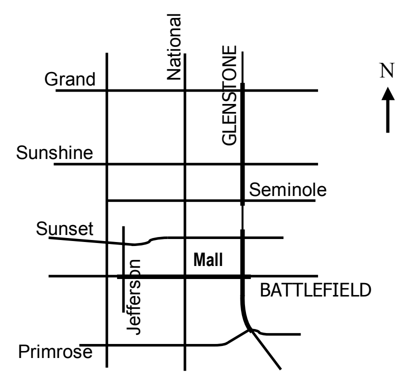

- GLENSTONE (north) US 65 business
  a north-south arterial commercial on both sides
  40 mph posted older development
  little access management

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- GLENSTONE (south) US 65 business
  a north-south arterial commercial on both sides
  40 and 45 mph posted newer development
  high level of access management

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- BATTLEFIELD
  an east-west arterial commercial on both sides
  40 mph posted newer development
  raised medians within 60 m (200 ft) of intersections

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Abutting Land Uses

- GLENSTONE (north)
  relatively small commercial tracts, scattering of highway-oriented businesses
- GLENSTONE (south)
  larger commercial tracts, big box stores, large shopping center
- BATTLEFIELD
  large commercial tracts and large shopping center, but also a few smaller commercial tracts

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Abutting Land Uses

- GLENSTONE (north)
  21 fast food and restaurant, 9 service stations, 22 shopping centers, 32 office/professional
- GLENSTONE (south)
  3 freestanding fast food and restaurant, 0 service stations, 13 shopping centers, 2 office/professional
- BATTLEFIELD
  10 fast food/restaurant, 2 service stations, 15 shopping centers, 14 office/professional

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Abutting Land Uses

NOTE:

- tracts along Battlefield are much deeper than those along Glenstone (north)

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Description of the 3 Segments

SEGMENT		LENGTH KM (MI)
Glenstone (north)	Little access management; Continuous center left turn lane; Many street & drive intersections	2.44 (1.51)
Glenstone (south)	High level of access mgmt.; Depressed center median; Few intersections	2.58 (1.61)
Battlefield	Some (not much) access mgmt.; TWLTL, raised median @ intersections; Fewer intersections than Glenstone (N)	2.51 (1.57)

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Volumes

SEGMENT	DAILY VOLUME	Σ of VOL. on SIGNALIZED CROSS STREET
Glenstone (north)	38,300	70,200
Glenstone (south)	31,500	66,100
Battlefield	28,900	97,900

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Intersections

	Glenstone (north)		Glenstone (south)		Battlefield	
	#	/km	#	/km	#	/km
SIGNAL	6 of 10	2.0	6 of 6	1.9	7 of 8	2.4
MEDIAN OPENINGS	na		6	1.9	na	
INTERSECT	114	46.3	8	2.7	69	27.1
STREET	10	3.7	6	1.9	8	2.8
DRIVE	104	42.6	2	0.8	61	24.3

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Geometric Characteristics

- All three streets have 4 through lanes.
- Battlefield and Glenstone (north) both have five-lane designs, w/ curb&gutter. Glenstone (south) has a depressed median, narrow shoulders, no curbs.
- All are relatively flat.
- Battlefield and Glenstone (north) are both straight. Glenstone (south) has a large radius horizontal curve.
- Glenstone (south) has some frontage roads.

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Travel Speed

- Lowest percent green
  - ♦ Battlefield - 24% at National intersection
  - ♦ Glenstone - 33% at Sunshine intersection

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Travel Speed

From moving vehicles in 1997-99, both peak and off-peak periods

Anywhere from 30 to 67 separate runs/direction

Segment ➔	Glenstone (north) NB	SB	Glenstone (south) NB	SB	Battlefield EB	WB
AVG. km/h	32.2	31.6	53.3	50.0	28.7	27.2
Mph	20.0	19.7	33.3	31.1	18.0	17.0

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4-year Crash Histories

	Glenstone (north)	Glenstone (south)	Battlefield
Crash / MVKm	8.5	6.8	11.7
Inj.+Fat. Crash / MVKm	2.5	2.0	3.1
Midblock Crash / MVKm	3.4	1.4	3.9
Intersection Crash / MVKM	1.5	1.7	1.9

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4-year Crash Histories - MIDBLOCK

Glenstone S
- ~ 1/2 either rear-end or following too close
- 1/4 to 1/3 angle

Battlefield
- ~ 1/2 either rear-end or following too close
- 1/4 to 1/3 angle

Glenstone N
- >80% rear-end or following too close
- angle almost non-existent

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4-year Crash Histories - INTERSECTION

- half or more on all 3 were rear-end or following too close
- Battlefield had higher proportion of angle crashes
- Glenstone (north) had almost double the proportion of sideswipe as Glenstone-south

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Comparison

- Similar ...
  - Arterial street
  - Commercial development
  - Segment lengths
  - Posted Speed
  - Volume
  - Number of through lanes
  - Signalized intersection frequency

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Comparison

- Different ...
  - Level of access management
  - Driveway/access spacing

Try to maximize similarities, limit differences so that level-of-access is one of the few significant differences

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Comparison

- Travel speed : over 50% higher on the access-managed street
- Crash rate : lower on the access-managed street
  - Lower mid-block seemed to explain the difference

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Comparison of 5-lane Designs

- Glenstone (north) has much higher driveway frequency .
- Battlefield had lower speed and higher crash rate

Slightly higher level of access management did not seem to improve Battlefield (note: Battlefield probably has more trips entering from the side).

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Acknowledgment

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ACCESS SPACING AND SAFETY:

RECENT RESEARCH RESULTS

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CONTENTS

Access Spacing and Safety:
Recent Research Results

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ABSTRACT

Over the past 40 years, more than 20 studies have shown how accidents increase with decreasing access spacing. These results have been well documented. Within the past several years, a number of additional research efforts have provided a further analysis of this basic relationship. These efforts include: (1) the multi-state accident investigation reported in NCHRP Report 420, (2) an accident model prepared for Indiana highways, (3) a comprehensive analysis of accidents versus access spacing in Minnesota, and (4) a conceptual analysis based upon the product of conflicting traffic volumes.

This paper compares the results of these recent studies, showing similarities and differences. In all studies, accident rates increase as access spacing is reduced. The volume-product approach and some of the empirical studies suggest that accident rates increase at approximately the square root of the increase in access points per mile.

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ACCESS SPACING AND SAFETY: RECENT RESEARCH RESULTS

Introduction

Many studies conducted over the past 40 years have shown how accident rates increase as access spacing decreases. This paper briefly summarizes the results of these studies. It then describes and compares the results of additional research efforts. These efforts include:

(1) a multi-state accident investigation performed in NCHRP Project 3-52 and reported in NCHRP Report 420[1],

(2) a comprehensive analysis of accident rates versus access spacing in Minnesota [2],

(3) an accident model for Indiana highways [3], and

(4) a conceptual accident analysis based upon the product of conflicting traffic volumes[4].

Early Studies

The results of 11 research efforts conducted between 1952 and 1975 are summarized in Table 1. Table 2 summarizes the principal results of 11 more recent studies conducted since the mid-1980s. Most of these studies were performed to help identify the impacts of access management.

The specific relationships vary reflecting differences in road geometry, (e.g. turn lanes, presence or absence of medians), operating speeds, and driveway and intersection traffic volumes. Still, in every case, more accidents mean more accidents.

Reported accident rates from four areas -- British Columbia, Florida, Michigan, and Oregon -- were plotted on a common scale versus access density. A series of indices were then prepared that keyed accident rates with access density by using the accident rates for 10 access points per mile as a base (total access points per mile on both sides of the road). The indices were averaged for each access density. The composite accident rate indices from the research review are summarized in Table 3. These indices suggest that the doubling of access frequency from 10 to 20 per mile increases the accident rate by about 30 percent. An increase from 20 to 40 access points per mile would increase accident rates by more than 60 percent. These increases are similar to those reported in Australia.

NCHRP Project 3-52 Safety Analysis

Comprehensive safety analyses were performed for accident information obtained from Delaware, Illinois, Michigan, New Jersey, Oregon, Texas, and Virginia. Overall, some 386 roadway segments were initially analyzed to explore the relationship between access spacing and accidents.

The initial accident database was stratified by the number of access points per mile (signalized and unsignalized), the area type (urban/rural), and the median treatment (undivided, two-way left-turn lane, and non-traversable median). Road segments without access points, road sections less than 0.31 miles long, and states with anomalies in the accident rates were excluded from further analysis.

The resulting database included 264 road segments -- 170 urban and 94 rural. Collectively, these sections contained about 37,500 accidents. They included data for Delaware, Illinois, Michigan, New Jersey, and Wisconsin. The accident reporting threshold in these states was generally about $500.

Urban and Suburban Areas. The urban road segments were further analyzed to screen road segments for characteristics or accident rates that did not appear consistent with the rest of the data. After the potential outliers were removed from the database, statistical analyses were prepared for 152 of the 170 road sections. Based upon this analysis, strata were selected for total access points per mile, signalized access points per mile, and unsignalized access points per mile. The signal density strata were set at less than or equal to 2, 2.01 to 4.0, 4.01 to 6, and more than 6 signals per mile. The other access density strata were set in increments of 20 access points per mile; less than 20, 20.01 to 40, 40.01 to 60, and more than 60 to minimize the number of cells with few points.

Means, coefficients of variation, students ‘t’ distribution statistics and p-values were computed and presented for each cell analyzed. The p-values represent the probabilities of differences between means occurring due to chance; thus, a 0.05 p-value is similar to a 5-percent level of significance.

A series of curves were derived based on the various cross-classification analyses. Figure 1 shows accident rates by median type and total access density for urban-suburban roadways. Representative accident rates by signalized and unsignalized access density are shown in Figure 2 for urban and suburban areas. These figures are shown for the midpoints of the unsignalized access spacing groups, and they reflect adjustments to eliminate apparent anomalies in the reported data.

In urban and suburban areas, each access points (or driveway) added would increase the annual accident rate by about 0.11 to 0.18 accidents per million VMT on undivided highways and by 0.09 to 0.13 on highways with TWLTLs or non-traversable medians.

Each unsignalized driveway may add about 0.02 to the accident rate at low signal densities, and from 0.06 to 0.11 at higher signal densities.

The generalized effects of access spacing on traffic accidents can be estimated by applying the suggested values of the accident rate indices, shown in Table 4, which were derived from the literature synthesis and safety analyses for urban/suburban areas. The suggested composite indices show the relative increase in accidents that may be expected as the total driveway density (in both directions) increases. These indices suggest that doubling the access frequency from 10 to 20 access points per mile would increase accident rates by 40 percent. A road with 60 access points per mile would have triple the accident rate (a 200-percent increase) as compared with a spacing of 10 access points per mile. Each additional access point increases the accident rate by about 4 percent.

Rural Areas. A similar analysis was performed for road segments in rural areas. Accident rates were stratified by total access density and median treatment. Signalized access density was not a separate variable, since the number of signalized access points in the rural database was small. Accident rates for Michigan were recalculated to remove animal-related and rail-crossing accidents.

After the potential outliers were eliminated form the database, some 89 segments were analyzed. Accordingly, three strata for total access points were identified to minimize cells with very few points -- less than 15 access points per mile, 15 to 30, and more than 30.

Means, coefficients of variation, and other statistical parameters were obtained for each of the three median types for each frequency. The curves shown in Figure 3 emerged from this analysis.

In rural areas, each access point (or driveway) added would likely increase the annual accident rate by 0.07 on undivided highways and by 0.02 on highways with TWLTLs or non-traversable medians.

Application. Accident rates will vary among states, because of different reporting thresholds and traffic conditions. Therefore, NCHRP Report 420 recommended that the accident rates should be obtained and used as the starting point for further analyses. The suggested values in Table 4 and graphs in Figures 1 to 3 may be used to assess the likely relative change in accident rates resulting from changes in access spacing.

Minnesota Accident Study, 1998

A comprehensive statewide accident study was prepared for the Minnesota Department Transportation by BRW. The study analyzed five rural and six urban road types. Some 432 road segments, involving 766 miles, 9,745 access points and 13,700 accidents were analyzed. A positive relationship between access density and accidents was found in 10 of 11 road categories analyzed. Accident rates increased with increasing street and commercial driveway access. An overview of principal findings follows

Table 5 describes the road categories analyzed. It also identifies the number of road segments, miles, accidents and the expected reliability for each category. Some 202 rural road segments and 230 urban road segments were analyzed with approximately 2,950 rural and 10,750 urban crashes, respectively. Access density averaged 7.8 access points per mile in rural areas and 27.9 per mile in urban areas. Accident rates were computed in the study for each road category as a function of the total access density.

Accident Rates. Table 6 summarizes the accident rates for the three rural road categories that had a high-expected reliability due to sufficient sample sizes.

Table 7 summarizes the accident rates computed for urban areas for the three arterial road types and one expressway road type with high-expected reliability. There is a consistent increase in accident rates as access density increases. These rates were then interpolated to obtain accident rates for specific access densities (i.e. 10, 20, 30, 40, 50, 60, and 70 access points per mile). The "over 50" category was assumed to extend from 50 to 80.

Table 8 gives the resulting accident rates and their corresponding indices. These indices are strikingly similar to those derived in NCHRP Report 420 (see Table 4 herein). In general, a doubling of access densities (i.e. from 10 to 20 per mile) results in a 40% increase in the accident rate.

Statistical Model. The BRW report also fit a negative binomial regression model to the accident data for each road category.

The basic model was:

$$\lambda_i = \lambda \, d_i^{\,b} \tag{1}$$

where:

λ_i = accidents per million VMT at site i
λ = base accident rate for all sites in the category
d_i = access density for site i
b = coefficient that governs access coefficient.

Table 9 summarizes the coefficients that were derived. The right hand column presents the ratio of accident rates resulting when the access density increases from 10 to 20 points per mile. Most of the ratios appear reasonably consistent with the 1.4 increase reported in NCHRP Report 420 and earlier analyses for Minnesota DOT.

Indiana Accident Study, 1999

Several studies in Indiana have analyzed the effects of cross sectional characteristics and access spacing on accidents. Research by Eransky, Tarko, and Sinha developed crash reductions factors for Indiana roads based on cross-sectional characteristics described in the state's road inventory database. (32) Separate negative binomial regression models were developed for rural two-lane, rural multi-lane, urban two-lane, and urban multi-lane highways. The level of access control was described by a qualitative variable with three levels.

Based on the initial results of the study, there were further investigations into the effects of access control and roadway features on accidents. (3) Negative binomial regression models were developed to predict the total number of crashes, number of property-damage-only crashes, and number of fatal and injury crashes. The exposure-to-risk variables include segment length, number of years, and AADT. The significant roadway factors include density of access points, proportion of signalized access points, presence of an outside shoulder, presence of a two-way left-turn lane, and presence of a median with no openings between signals.

Multi-lane road sections were selected for analysis in cooperation with the Indiana Department of Transportation. These sections were located in urban and suburban areas throughout the state and represent a wide array of geographic locations and levels of access control. Some 23 sections of road were analyzed along about 75 miles (120 km) of 18 state highways located in 12 counties. These road sections were subdivided into 155 segments that were homogeneous with respect to cross section and traffic volume.

Data Collection. A Road Inventory Data Bank maintained by Indiana DOT provided traffic and geometric data for the selected road segments. The number and type of access points were identified from a video log database. Accident information was obtained from Indiana DOT's crash database, and adjustments were made to account for missing accidents. In most cases, crash data for the 5-year period from 1991 to 1995 were used. However, for a few road segments that underwent improvements between 1991 and 1995, crash data for three years were used to ensure that the segments had consistent cross-section characteristics.

Statistical Models. Once the crash and segment data were collected, statistical models were developed to predict the number of total crashes, number of fatal and injury crashes, and number of property damage crashes. A negative binomial regression model was used; the access density was calculated as the total number of access points divided by the segment length. The total number of access points includes both signalized and unsignalized access points at a given location from one side or from both sides. For unsignalized intersections, a T-intersection (one-sided access point) was considered at one access point, while a four-leg intersection (two-sided access points) was considered at two access points. Signalized intersections were considered as two access points regardless of the number of legs, probably because signals stop traffic in either direction on the segment. Access points within 30m of the segment endpoints were not considered.

Separate models were developed using stepwise regression to predict the total number of crashes, number of property damage only crashes, and number of fatal/injury crashes. The resulting R^2 values were slightly below 0.5. These models were then rerun to account for missing crashes by applying an adjustment factor of 1.61.

The final equation for total accidents, after adjustments for missing accidents was as follows:

$$C = 0.494\, L * Y * V * \exp\,(0.0285A - 0.631S + 2.520p - 0.748t - 0.604m) \qquad (2)$$

where:

C = expected number of total accidents
L = length of road section (km)
Y = number of years
V = annual average daily traffic
A = access points per km
S = dummy variable to indicate presence of shoulder (1 if outside shoulder is present, 0 otherwise)
p = proportion of access points that are signalized
t = dummy variable to indicate presence of two-way left turn lane on segment (1 if two way left turn lane, 0 otherwise)
m = dummy variable to indicate segment without medians (1 if segment has no median, 0 otherwise)

Results. The coefficients of equation 2 confirm the results of previous safety studies, such as those set forth in NCHRP Report 420 (A positive coefficient indicates an increase in expected accidents, and a negative coefficient indicates a decrease).

1. Segments with more frequent access points experience more accidents.

2. The presence of an outside shoulder leads to a reduction in accidents. An outside shoulder may result in larger turning radii at access points.

3. The presence of traffic signals can lead to higher accident rates. This may reflect the higher likelihood of rear-end collisions where vehicles are stopped at traffic signals.

4. The presence of a two-way left-turn lane leads to a reduction in accidents by separating through and left turn vehicles.

5. The presence of a median with no openings between signals also leads to a reduction in crashes.

Equation 2 was also used to assess the effect of access density in two cases.

(a) Suburban arterial streets with shoulders and access onto arterial facilitated only through unsignalized right turns,

(b) Urban arterial streets without turning restrictions and with some access points signalized (a typical proportion of 8% was assumed).

The safety effect was measured by the number of reported crashes per million kilometers traveled.

The accident rates for urban streets are over four times higher than those for suburban roads. This is because there are restrictions on left-turning movements, availability of shoulders, and absence of traffic signals at minor intersections along the suburban arterials. The study reported that ten additional access points are associated with a 32% increase in the total number of accidents.

Accident rate indices were then derived, using 10 access points per mile as a base. These indices are shown in Table 10. These indices are comparable to those reported in NCHRP 420 for access densities of over 50 access points per mile, but are slightly less at lower access densities

Conceptual Analysis

A conceptual analysis for predicting the safety of arterial roads based on arterial traffic volumes, access volumes on intersecting streets and driveways, and access point density was developed by Levinson (4). This method applies the long-established relationship between intersection accidents and the product of conflicting volumes. The simplifying assumption that access points have approximately equivalent volumes made it possible to derive safety indices that relate directly to the change in access density.

The ratio of the expected accidents as a function of changes in access density was found to be expressed by the following equation.

$$\frac{N_2}{N_1} = \frac{n_2}{n_1}\left(\frac{n_1}{n_2}\right)^b \qquad (3)$$

where N_2 = accidents after
N_1 = accidents before

n_2 = access points after
n_1 = access points before
b = coefficient

If the exponent b=0.5, this relationship becomes:

$$N_2 / N_1 = \sqrt{\frac{n_2}{n_1}} \qquad (4)$$

This equation suggests that the relative change in accidents is approximately equal to the square root of the ratio between changes in access frequency. Thus, a change from 10 to 20 driveways per mile would result in a 41% increase in accidents.

Table 11 gives the relative changes in accident potential (exposure as the number of access points over a given section of road increases). The values assume that the total access driveway volumes remain constant and that the individual access volumes would be about equal. The table gives estimated changes for b coefficients of 0.5 and 0.633. Values were reported in past studies. (29, 30, 31)

Comparisons and Conclusions

The various safety analyses clearly indicate that accident rates rose with increasing access density. The relative rates of increase, expressed as accident indices presented in Table 12, show how remarkably consistent the patterns are. A doubling of access density from 10 to 20 access points per mile results in a 40% increase in the expected accident rates; an increase to 40 results in about a 2.0 time increase. The "square root rule"—in which accident rates rise with the square root of the ratio of the increase in access density provides a close approximation of reported rates, especially where access densities are less than 50 points per mile.

Obviously, site specific conditions will influence the actual accident experience along any highway. Horizontal and vertical alignment, sight distance, access road designs, and type of intersection controls will influence safety. However, the "exposure indices" provide a benchmark against which such factors can be assessed.

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Figure 1

ESTIMATED ACCIDENT RATES BY TYPE OF MEDIAN; URBAN AND SUBURBAN AREAS

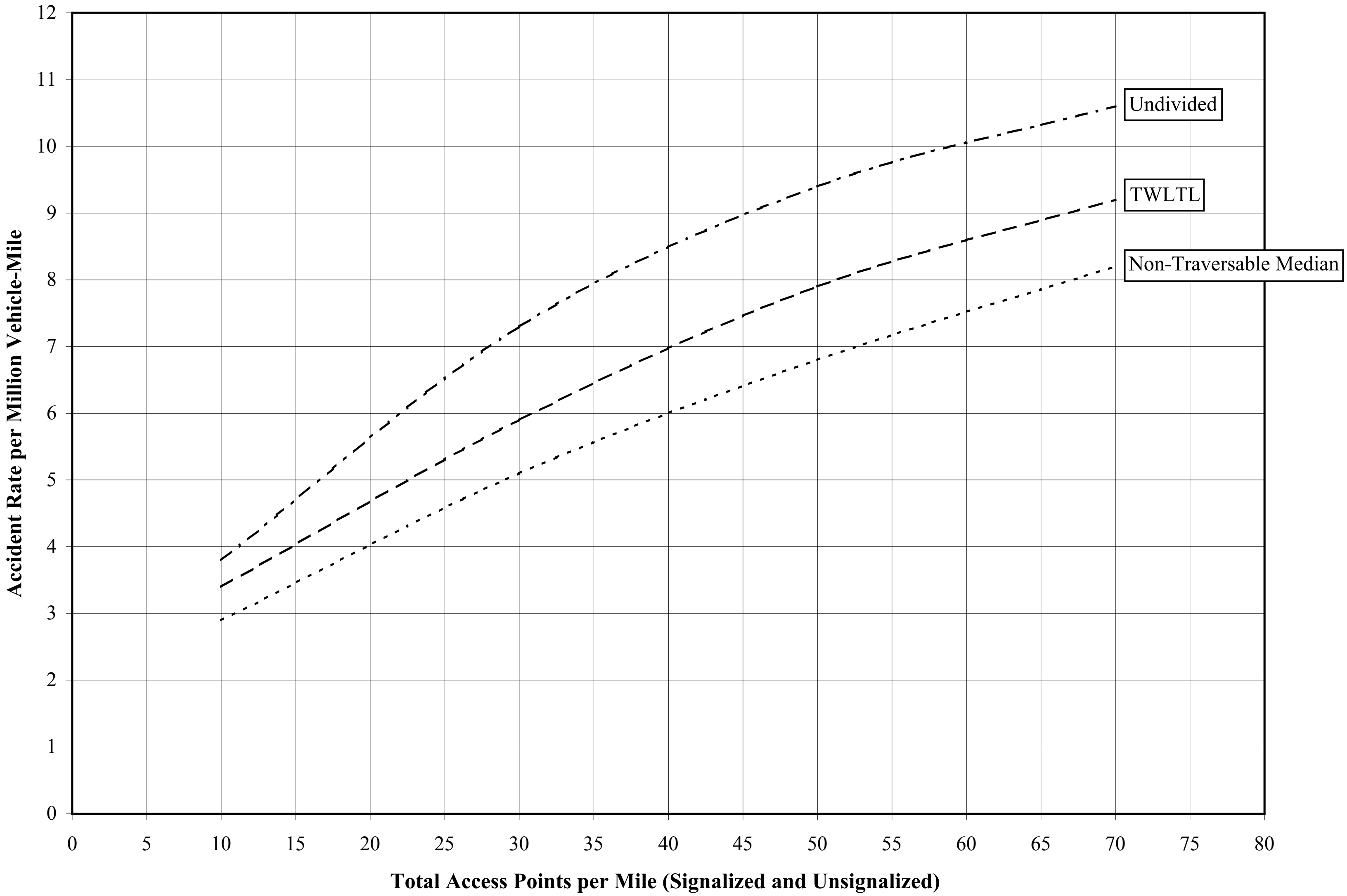


Table 1

Chronology of Accident Studies
Relating to Access Spacing
1952-1975

Study No.	Year	Description	Findings	Source
1	1952	McMonagle, Michigan	An increase from 0 to 4 or more roadside features per 1,000 feet increases accidents/million VMT from 3.37 to 13.48	(5)
2	1953	Staffeld, Minnesota	Roadways with more than 20 access points per mile had more than double the rates of roads with less than 4 access points per mile	(6)
3	1957	Schoppert, Ohio	The number of access points along rural two-lane highways is a reasonably good predictor of potential accidents within an ADT group.	(7)
4	1959	Head, Oregon	Accident rates increased as the number of commercial driveways and/or commercial units per mile increased.	(8)
5	1967	Cribbins et al, North Carolina (92 road sections)	Accident and injury rates on multi-lane divided highways increased as the number of access points and their traffic volumes increased.	(9)
6	1967	Mulinazzi and Michael, Indiana (100 road sections)	The number of medium and heavy volume commercial driveways per mile was significantly related to the accident rates for sections with less than 5,800 ADT.	(10)
7	1970	Dart and Mann, Louisiana	Accident rates doubled as the traffic conflicts increased ten times.	(11)
8	1970	Interstate System – Accident Research	As intersections/mile increased from 1 to15: accident rates increased 4 to 5 times on urban highways and 2 to 3 times on rural highways. As business access points/mile increased from 1 to 40: accident rates doubled	(12)
9	1973	McGuirk, Indiana (63 miles)	Accidents per mile may decrease when the number of commercial driveways, traffic volumes, or travel lanes is reduced.	(13)
10	1974	Uckotter, Indiana (14 road sections)	Regression equations produced counter intuitive results.	(14)
11	1975	Glennon et al	An increase from low to high driveway frequency doubles annual accident frequency . An increase from low to high volumes (over 15,000 ADT) triples annual accidents.	(15)

Table 2

Chronology of Accident Studies
Relating to Access Spacing
Since Mid 1980s

Study No.	Year	Description	Findings	Source
1	1985	Arapahoe and Parker Roads, Denver (4.35 and 5.16 miles)	Two highly access managed roads had about 40% the accident rate of roads with frequent access.	(16)
2	1986	Waushara County, Wisconsin	Annual accidents per mile for access spacing less than 300 feet was about 2 to 3 times greater than for longer spacing.	(17)
3	1992-1993	Sokolow, Long et al, Florida	Accident rates doubled when driveways exceeded 20 per mile (Sokolow). Accident rates increased 70% as driveways per mile increased from less than 13 to more than 20 (Long, et al).	(18, 19)
4	1993	British Columbia (176 road sections, 465 miles)	Accident rates increased as access density increased. Each business access impacted accident rates about 50% of public road intersections	(20)
5	1993	Millard, Lee County, Florida	Doubling connections from 20 to 40 per mile doubled the accident rate. Doubling signals from 2 to 4 per mile, more than doubled the accident rate.	(21)
6	1994	Michigan	Midblock accident rates generally increased as the number of intersections per mile (including driveways) and the number of lanes increased.	(22)
7	1995	Fitzpatrick & Balke, Texas	Total and midblock accidents generally increased as driveways became more numerous.	(23)
8	1995	Lall et al, Oregon (US Route 101 – 29 miles)	Accidents per mile and driveways per mile followed similar patterns (except for road sections with a non-traversable median).	(24)
9	1996	Norwalk-Wilton, Connecticut (Route 7)	Accident rate per mile increased along roadway carrying 20,000 to 25,000 vehicles per mile as access density increased.	(25)
10	1996	Garber & White, Virginia (10 miles 30 locations)	Multiple regression analysis assessed effects of ADT/lane, average speed, number of access points, left-turn lane availability, average access spacing and average difference in access spacing.	(26)
11	1997	Australia	Each additional driveway per km increased accident rates about 1.5 % for 2-lane roads and 2.5 % for 4-lane roads.	(27)

Table 3

Composite Accident Indices
(Literature Review)

Access Points per mile	**Accident Index (Ratio to rates for 10 access points per mile)**
10	1.0
20	1.3
30	1.7
40	2.1
50	2.8
60	4.1

Source: (1)

Table 4

Suggested Accident Indices
For Unsignalized Access Spacing

Access Points Per Mile*	(A) Literature Synthesis	(B) Safety Analysis	(C) Suggested Value
10	1.0	1.0	1.0
20	1.3	1.4	1.4
30	1.7	1.8	1.8
40	2.1	2.1	2.1
50	2.8	2.3	2.5
60	4.1	2.5	3.0
70	---	2.9	3.5

*Total for both directions.

Source (1)

Table 5

Segment and Accident Data for Minnesota Road Sections

Road Class	Description	Road Segments	Miles	Accidents (Crashes)	Expected Reliability
Rural					
RC2NLT	2 lane	120	412	1191	High
RC2LT	2 lanes with left turn lanes	14	21	156	Moderate
RC4	4 lanes	36	68	793	High
RC6	6 lanes	7	7	130	Low
RE4	4-lane expressway	25	80	679	High
	Rural Subtotal	202	588	2949	
Urban					
UC2NLT	2 lanes	58	38	803	High
UC4NLT	4 lanes	48	29	2116	High
UC6	6 lanes	17	14	763	Low
UC2LT	2 lanes with left turn lanes	20	14	733	Moderate
UC4LT	4 lanes with left turn lanes	42	33	2613	High
UE4	4-lane expressway	45	50	3723	High
	Urban Subtotal	230	178	10751	
	Total	432	766	13700	

Source: (2)

Table 6

Summary of Rural Crash Rates by Access Density

Road Type	**Rural Density (Access Points Per Mile)**			
	0-5	**5-10**	**10-15**	**>15**
RC 2 NLT	0.82	0.99	1.34	1.25
RC 4	0.93	1.10	2.79*	
RE4	0.62			0.80

*Over 10 points per mile

Source: (2)

Table 7

Summary of Urban Crash Rates by Access Density

Road Type	Density			
	0-10	**10-30**	**30-50**	**Over 50**
UC 2 NLT	1.68	2.64	4.91	6.02
UC 4 NLT	2.22	3.34	4.74	7.38
UC 4 LT	2.56	4.51	5.79	10.40
UE 4	1.23	1.77	N/A	N/A

Source: (2)

Table 8

Summary of Interpolated Urban Accident Rates by Access Density

Access Points Per Mile	Accident Rate					
	UC 2 NLT		UC 4 NLT		UC 4 LT	
	Rate	Index	Rate	Index	Rate	Index
10	2.00	1.0	2.40	1.0	3.20	1.0
20	2.64	1.3	3.34	1.4	4.51	1.4
30	3.78	1.9	4.04	1.7	5.15	1.6
40	4.91	2.5	4.74	2.0	5.79	1.8
50	5.32	2.7	5.70	2.5	8.00	2.3
60	5.75	2.9	6.62	2.8	9.25	2.9
70	6.02	3.1	7.34	3.1	10.40	3.2

Source: Computed

Table 9

Results of Statistical Analyses

Road Class	**Description**	**λ**	**a(1)**	**b(2)**	**Estimated Ratio in accident rate – going from 10 to 20 access points per mile**
Rural					
RC 2	Rural 2 lanes	0.500	0.265	0.39	1.31
RC 4 & 6	Rural 4 & 6 lanes	0.385	0.378	0.82	1.77
RE – 4	Rural 4 lane Expressway	0.330	0.137	0.47	1.38
Urban					
UC 2	Urban 2 lanes	1.340	0.421	0.32	1.24
UC 4 & 6	Urban 4 and 6 lanes	1.290	0.306	0.35	1.27
UE 4	Urban 4 lane Expressway	0.640	0.215	0.61	1.52

Source: (28)

Notes:

1. Measures over dispersion when compared to the Poisson models.
2. A coefficient that relates access density to accident rate.

Table 10

Derived Accident Rate Indices for Indiana Urban and Suburban Arterials

Access Points per mile	Index
10	1.0
20	1.2
30	1.5
40	1.8
50	2.1
60	2.5
70	3.0

Source: Computed

Table 11

ANTICIPATED SAFETY IMPACTS
FROM CHANGING DRIVEWAY SPACING
(For a given access volume)

Driveway Density Ratio After/Before	b=0.5		b=0.633	
	Exposure Index After/Before	% Change	Exposure Index After/Before	% Change
0.10	0.32	68	0.43	57
0.20	0.45	55	0.55	45
0.30	0.55	45	0.65	35
0.40	0.63	37	0.71	29
0.50	0.71	29	0.78	22
0.60	0.77	23	0.83	17
0.70	0.83	17	0.88	12
0.80	0.89	11	0.92	8
0.90	0.95	5	0.96	4
1.00	1.00	0	1.00	0
1.50	1.22	22	1.16	16
2.00	1.41	41	1.29	29
2.50	1.58	58	1.40	40
3.00	1.73	73	1.50	50
4.00	2.00	100	1.66	66
5.00	2.24	124	1.81	81
6.00	2.45	145	1.93	93
7.00	2.65	165	2.04	104

Source: Computed

Table 12

Comparison of Accident Rate Indices

	NCHRP 420 Literature Synthesis	NCHRP 420 Safety Analysis	Minnesota Study				Indiana Study	Square Root Rule
Reference Table	**Table 3**	**Table 4**	**Table 8**				**Table 10**	**Table 11**
Roads	**All Roads**	**Urban-Suburban Roads**	**Urban-Suburban Roads**				**Urban-Suburban Roads**	**All Roads**
			UC 2 NLT (1)	**UC 4 NLT (2)**	**UC 4 LT (3)**	**Average**		
Access Points Per Mile								
10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
20	1.3	1.4	1.3	1.4	1.4	1.4	1.2	1.4
30	1.7	1.8	1.9	1.7	1.6	1.7	1.5	1.7
40	2.1	2.1	2.5	2.0	1.8	2.1	1.8	2.0
50	2.8	2.3	2.7	2.5	2.3	2.5	2.1	2.2
60	4.1	2.5	2.9	2.8	2.9	2.9	2.5	2.5
70	NA	2.9	3.1	3.1	3.2	3.1	3.0	2.7

Source: Computed

(1) 2 lanes – No left turn lanes.
(2) 4 lanes – No left turn lanes
(3) 4 lanes – With left turn lanes

Figure 2

ESTIMATED ACCIDENT RATES BY ACCESS DENSITY; URBAN AND SUBURBAN AREAS

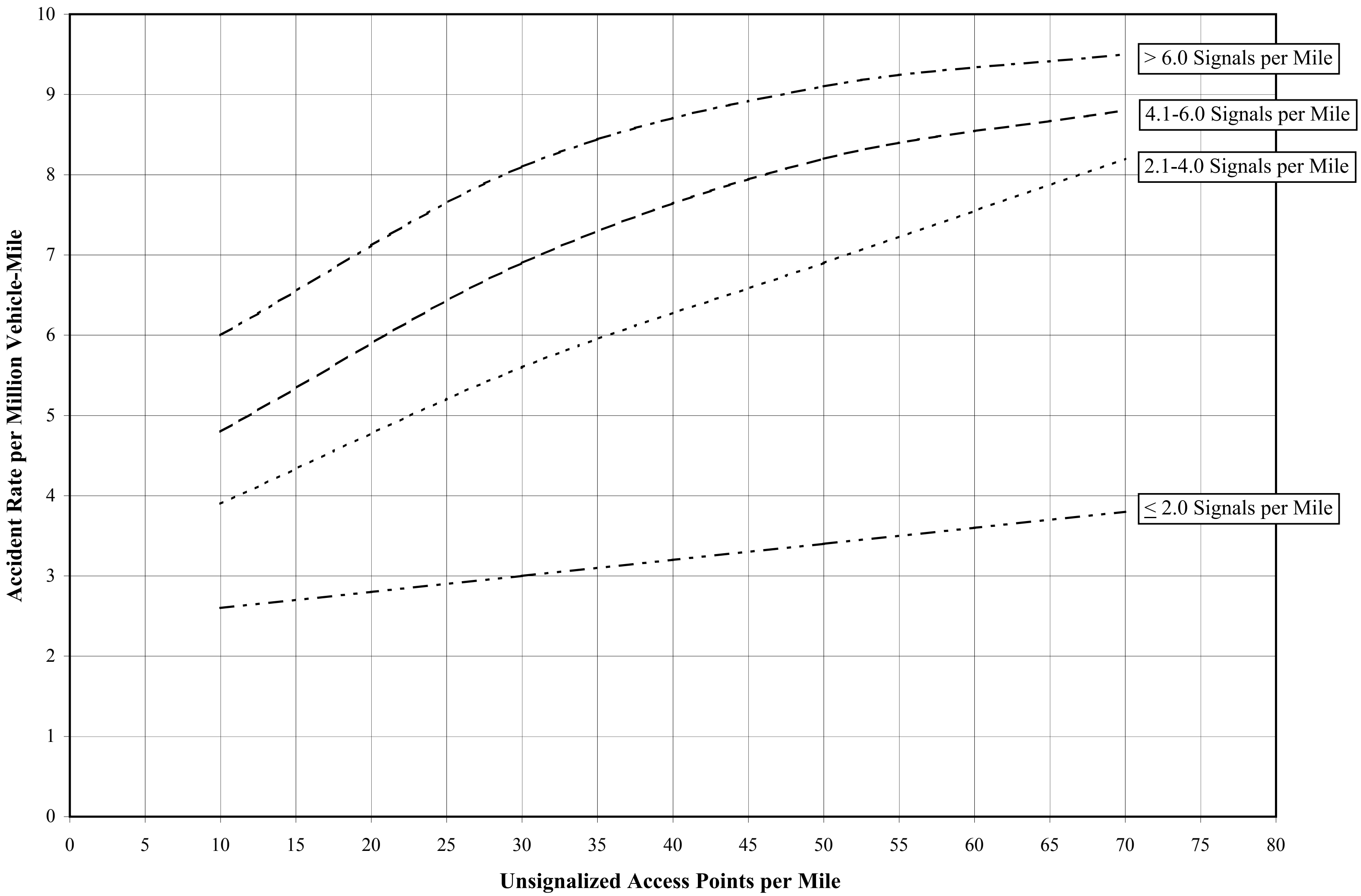
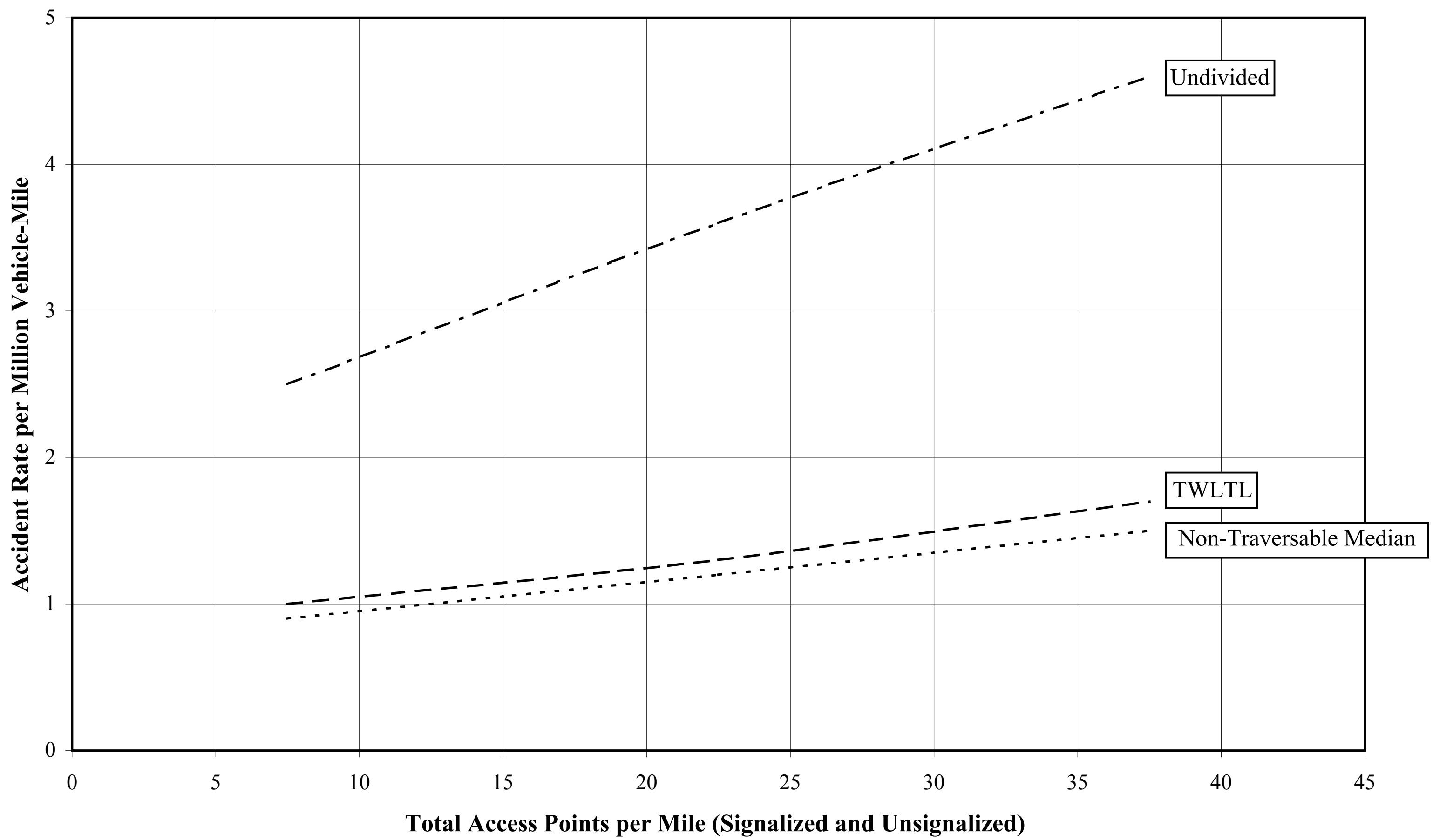


Figure 3

ESTIMATED ACCIDENT RATES BY TYPE OF MEDIAN; RURAL AREAS



Traffic Safety vs Access Management

By: Raj Shanmugam, P.E., and Jan Thakkar, P.E.

INTRODUCTION

Growing traffic congestion, concerns over traffic safety, and the ever increasing cost of upgrading our roads have given birth to a new interest in access management. By managing the access to the highway system, we can help to provide transportation that is more efficient and safe. A familiar example of inefficient and unsafe highway management is the "strip" development that present a driveway every few feet. It is not only stressful to know a vehicle could come out of each of this driveway at any time, but it is also costly and can wreck the efficiency and safety of our highway system.

A comprehensive access management means more than the control of driveways. Research have shown that the management of driveways is just one aspect of access management. To support a comprehensive access management program, we must not only manage driveways but also medians, median openings, the spacing of traffic signals, and the spacing of freeway interchanges. The measurable improvements to our road system which can be accomplished through a program of comprehensive access management include fewer accidents per million vehicle miles traveled, increased capacity of our highways, and shorter travel time. Studies in Colorado, Florida and other parts of the country have shown that accident rate per million vehicle miles traveled can be 50% less on arterials that have good access management. In a study done for the Florida Department of Transportation, analysis showed that the typical 4-lane arterial with a high level of access management can handle 10,000 more vehicles per day than the same 4-lane road without a high level of access management. An analysis of major road improvements in Fort Lauderdale, Florida, showed significant benefits from the installation of more restrictive medians access points.

When Florida examined its options for access management standards, it took the concept of access separation and speed differential a step further. Designing accesses that only provide a short distance between crashes was not enough for our new highways. Florida's access spacing standards take into account a greater comfort for safety and also encourages "Functional Integrity". The standards were developed based on research conducted throughout the United States regarding safe stopping sight distances, speed differential and other factors.

On February 13, 1991, the Florida Department of Transportation (FDOT) adopted Administrative Rule Chapter 14-97 regarding access management standards for the State Highway System. This rule called the "Standards Rule" establishes the seven classifications for the state highways and the criteria and procedures for assigning these classifications to specific roadways. The rule sets forth a series of roadway classifications based on spacing between traffic signals, median openings and connections (i.e., driveways and public streets). Essentially, the Department of Transportation determines which roads are the most critical to providing high speed, high volume traffic, and these end up with the highest of standards. Those roads that serve a higher access function will receive a lower classification. This Rule was adopted by the State to implement the State Highway System Access Management Act which was passed by the Florida Legislature in 1988. The purpose for the legislation, as stated in Section 14-97.001 of the rule "....is to protect public safety and general welfare,......"

FDOT Access Management - Arterial Classifications & Standards

CLASS	*MEDIANS*	*CONNECTION*		*MEDIAN OPENING*		*SIGNAL*
		> 45 mph	*< 45 mph*	*Directional*	*Full*	
GENERALLY DEVELOPING OR UNDEVELOPED AREAS						
2	**Restrictive w/ Service Roads**	**1320'**	**660'**	**1320'**	**2640'**	**2640'**
3	**Restrictive**	**660'**	**440'**	**1320'**	**2640'**	**2640'**
4	**Non-Restrictive**	**660'**	**440'**			**2640'**
GENERALLY DEVELOPED						
5	**Restrictive**	**440'**	**245'**	**660'**	**2640'/1320'**	**2640'/1320'**
6	**Non-Restrictive**	**440'**	**245'**			**1320'**
7	**Both Median Types**	**125'**		**330'**	**660'**	**1320'**

In June 1993, the FDOT District IV Office which comprises of Broward, Palm Beach, Martin, St. Lucie and Indian River Counties assigned roadway classifications for the purposes of access management to all state maintained roadways. Although one of the primary intent behind access classification was to protect public safety, the accident history along these corridors was only one of fourteen(14) criteria used to assign the access classification. The fourteen(14) Qualitative and Quantitative criteria used in the access classification include:

<u>Qualitative</u>

1. Existing and future functional classification
2. Presence of planned improvements
3. Development density
4. Type of Drainage/edge treatment
5. Existing and future land uses
6. Local street network/frontage roads
7. Potential for access restriction/new median

<u>Quantitative</u>

8. Number of through lanes
9. Posted Speed limit
10. Existing and future traffic volumes
11. Accident history
12. Driveway density
13. Median opening density
14. Signal spacing

<u>STUDY PURPOSE</u>

The primary purpose behind this study is to compare the accident statistics between different classes of roadways to test the significance of difference in accident experience.

STUDY PROCEDURE

Majority of arterial roadways in District IV are assigned either Class 3, 4, 5, 6, or 7 access classification. Therefore, the following six(6) segments of state roadways in Broward County are selected to compare the accident history (1996 through 1998) between segments of same roadways that are continuous and being assigned Class 3 versus Class 5.

Study Segment Characteristics

Roadway Segment	FROM	TO	Length	Class	Signals/mi.	Medians/ mi.	Connections/ mi.
1. State Road 5	Dania Canal Bridge - BMP 0.000	State Road 84 - EMP 2.547	2.547	3	1.2	2.4	12.2
(US 1)	State Road 84 - BMP 8.286	Broward Blvd. - EMP 10.330	2.044	5	1.5	8.3	68.5
2. State Road 7	Orange Drive - BMP 6.467	I 595 - EMP 7.782	1.315	3	1.5	3.8	16.0
(US 441)	Stirling Road - BMP 5.090	Orange Drive - EMP 6.467	1.377	5	2.2	8.0	50.8
3. State Road 7	Coral Gate Drive - BMP 20.438	P.B. County Line - EMP	4.153	3	1.0	3.6	9.8
(US 441)	McNab Road Bridge - BMP	Coral Gate Drive - EMP	4.240	5	2.8	10.1	53.8
4. State Road 816	University Dr. - BMP 0.000	N.W. 56th Avenue - EMP 1.847	1.847	3	2.7	8.1	28.2
(Oakland Pk. Bld)	N.W. 56th Avenue - BMP 1.847	US 441 - EMP 3.329	1.482	5	5.4	7.4	27.0
5. State Road 84	East of S.R. 7 - BMP 16.080	S.W. 15th Ave. - EMP 18.177	2.097	3	1.0	3.8	29.1
(SE 24th Street)	S.W. 15th Ave. - BMP 18.177	Miami Road - EMP 19.776	1.599	5	3.8	8.8	75.7
6. State Road 817	Dade County Line - BMP 0.000	S.W. 6th St. - EMP 9.825	9.825	3	2.1	7.7	22.2
(University Dr.)	S.W. 6th St. - BMP 9.825	Sample Road - EMP 21.003	11.178	5	3.0	7.7	31.8

The Florida Department of Transportation prioritize roadway segments for safety purposes based on a methodology that uses both the accident frequency and accident rates, referred to as Safety Ratio.

$$\text{Safety Ratio} = \frac{\text{Actual Accident Rate}}{\text{Critical Accident Rate}}$$

The Actual Accident Rate is a function of a segment length times the annual number of vehicles in relation to the number of accidents. The Critical Accident rate is a function of segment length, traffic volume, and the average accident rate for the category of roadway being tested. Therefore, segments of roadways with different cross sections cannot be objectively compared. The test segments being continuous lend to similar cross sections and eliminate the potential for discrepancies.

Crash Data (95,96,97) Summary

Roadway Segment	1995 Crash Statistics							1996 Crash Statistics							1997 Crash Statistics						
	Safety	Crash	ADT	RE	ANG	LT	RT	Safety	Crash	ADT	RE	ANG	LT	RT	Safety	Crash	ADT	RE	ANG	LT	RT
1. State Road 5	0.196	39	50,731	15	8	5	1	0.188	35	53,286	11	10	8	0	0.231	51	53,108	25	10	1	0
(US 1)	0.806	132	54,500	56	17	11	2	1.030	163	54,500	62	25	17	9	0.814	150	56,060	71	23	22	2
2. State Road 7	0.271	29	46,517	11	4	5	0	0.225	24	47,250	12	2	1	0	0.283	34	49,074	17	3	0	2
(US 441)	1.133	93	46,000	34	17	19	6	1.004	77	46,000	30	12	16	2	1.271	102	45,324	45	21	11	1
3. State Road 7	0.413	104	40,000	49	21	17	1	0.321	79	40,044	40	11	7	0	0.281	80	40,938	40	7	11	4
(US 441)	1.971	450	39,027	188	65	76	8	1.483	323	37,907	134	60	51	10	0.891	230	42,495	124	37	21	2
4. State Road 816	0.482	66	45,500	28	14	7	3	0.636	85	45,500	25	17	14	1	0.496	74	45,000	32	12	14	0
(Oakland Pk. Bld)	1.708	199	47,219	109	34	12	7	1.635	185	46,938	113	20	8	6	1.423	180	46,500	104	21	13	2
5. State Road 84	0.488	64	49,977	17	18	0	2	0.373	57	50,263	10	13	4	3	0.707	73	34,616	19	19	3	2
(SE 24th Street)	0.514	59	44271	14	19	10	0	0.507	59	44,514	16	21	8	1	0.732	67	29,119	17	18	14	0
6. State Road 817	0.958	683	51,947	330	114	100	19	0.983	703	53,592	371	87	119	14	1.099	886	53,063	466	126	116	32
(University Dr.)	1.154	860	47880	429	140	106	27	1.010	761	49,793	390	135	86	18	0.871	752	50,141	363	100	84	38

Study Segments - Access Class 3 & 5

Roadway Segment	FROM	TO	Exception	Length	Class
1 SR 5 (US 1)	0.000/DANIA CANAL BRIDGE	2.357/SR 84-SE 24 STREET		2.357	3
	8.381/SR 84-SE 24 STREET	10.235/SR 842-BROWARD BLVD		1.854	5
2. SR 7 (US 441)	6.656/ORANGE DRIVE-SW 45	7.582/SR 862-I 595		0.926	3
	5.184/SR 848-STIRLING ROAD	6.372/ORANGE DRIVE-SW 45		1.188	5
3. SR 7 (US 441)	20.600/CORAL GATE DRIVE-NW	24.402/PALM BEACH COUNTY		3.802	3
	16.297/McNAB-CYPRESSCREEK	20.316/CORAL GATE DRIVE-NW		4.019	5
4. SR 816 (Oakl Pk.Bld)	0.189/SR 817-UNIVERSITY	1.657/INVERRARY BLVD-NW 56		1.468	3
	1.941/INVERRARY BLVD-NW 56	3.234/SR 7		1.293	5
5. SR 84 (SE 24^{th}St.)	16.269/E OF SR 7	17.987/SW 15 AVENUE		1.718	3
	18.271/SW 15 AVENUE	19.681/MIAMI ROAD	19.272-19.462/RR XING	1.220	5*
6. SR 817 (Univ. Dr.)	0.189/DADE COUNTY LINE-	9.649/SW 6 STREET		9.460	3
	9.932/SW 6 STREET	20.908/SR 834-SAMPLE ROAD		10.976	5
7. SR 820 (Pines Blvd.)	0.189/SR 25-US 27	11.297/SR 817-UNIVERSITY		11.108	3
	11.580/SR 817-UNIVERSITY	13.902/SR 7-N 60 AVE		2.322	5
8. SR 814 (Atlan. Blvd.)	0.189/SR 7-US 441	2.293/SR 849-NW 31AVE		2.104	3
	3.322/SR 849-NW 31AVE	7.775/SR A1A-N OCEAN	4.774/EB EXIT TO SB SR 9-I 95	3.909	5*
9. SR 834 (Sample Rd.)	0.189/SR 817-UNIVERSITY	7.427/WB ENT FROM SB SR 9-I		7.235	3
	8.032/EB ENT FROM SR 9-I 95	9.396/SR 5-US 1		1.364	5
10. SR 842 (Browd Blvd.)	0.189/SR 817-UNIVERSITY	2.950/SR 7		2.761	3
	3.234/SR 7	7.071/SR 5-US 1	4.992/EB EXIT TO SR 9-I 95,	3.441	5*
11. SR 848 (Stirling Rd.)	0.189/SR 817-UNIVERSITY	2.466/SR 7-N 60 AVE		2.277	3
	2.750/SR 7-N 60 AVE	6.631/SR 5-US 1	5.132-5.322/RR XING, 5.437 I-95	3.691	5*
12. SR 870 (Comrcl Bld)	0.189/SR 817-UNIVERSITY	6.059/SR 845-POWERLINE		5.870	3
	6.342/SR 845-POWERLINE	9.798/SR A1A-OCEAN-NE 50	6.303/WB ENT FROM SB SR 9-I 95	2.970	5*

Crash Data Analysis Summary for Class 3 & 5 Study Segments (1996, 1997, & 1998 Data)

Roadway Segment	Acce. Class	Safety Ratio			Crash Frequency				ADT			THREE YEAR AVERAGES				Crash Rate (acc./ mvm.)
		1996	1997	1998	1996	1997	1998	TOTA	1996	1997	1998	RE	ANG	LT	RT	
1. SR 5	3	0.157	0.191	0.233	27	39	45	111	52,111	51,756	56,700	40	16	13	0	0.80
(US 1)	5	0.811	0.691	0.694	114	116	106	336	52,917	56,030	54,311	151	55	32	6	3.04
2. SR 7	3	0.274	0.306	0.355	20	27	27	74	45,000	49,000	42,500	43	6	4	0	1.60
(US 441)	5	0.809	0.710	1.017	53	49	59	161	45,000	46,092	43,102	73	30	15	3	2.77
3. SR 7	3	0.326	0.286	0.319	74	74	93	241	40,000	40,331	47,425	114	23	35	7	1.36
(US 441)	5	1.396	0.842	0.720	307	207	203	717	41,627	42,895	43,272	337	124	87	19	3.82
4. SR 816	3	0.309	0.360	0.345	37	44	43	124	50,500	45,000	47,500	38	16	29	3	1.62
(Oakl Pk.Bld)	5	1.382	1.466	1.626	148	160	181	489	50,500	45,000	47,500	300	50	31	9	7.25
5. SR 84	3	0.365	0.609	0.515	31	50	43	124	29,000	28,000	32,000	33	30	4	9	2.22
(SE 24thSt.)	5*	0.892	0.911	0.839	47	61	52	160	22,563	30,187	27,489	34	52	34	0	4.48
6. SR 817	3	1.067	1.108	0.991	679	863	748	2290	49,191	53,127	53,055	1188	327	319	71	4.27
(Univ Dr.)	5	1.009	0.838	0.807	727	720	685	2132	48,382	50,803	51,692	1059	325	240	75	3.53
7. SR 820	3	0.707	0.909	1.035	366	582	692	1640	37,727	42,807	49,553	963	148	185	39	3.11
(Pines Blvd.)	5	0.889	1.042	1.110	104	162	160	426	31,115	37,500	35,500	179	71	63	11	4.83
8. SR 814	3	0.622	0.487	0.407	95	93	71	259	46,500	52,000	48,500	115	52	20	1	2.29
(Atlan Blvd.)	5*	0.983	1.084	0.961	329	321	284	934	51,174	44,304	44,208	447	170	83	17	4.69
9. SR 834	3	1.048	0.640	0.691	442	388	418	1248	43,515	56,201	57,073	685	191	132	15	3.01
(Sample Rd.)	5	0.941	1.068	1.113	83	86	96	265	38,235	29,953	33,500	94	65	48	3	5.23
10. SR 842	3	0.376	0.369	0.373	69	75	75	219	43,493	42,567	43,253	72	55	37	2	1.68
(Browd Blvd.)	5*	0.877	0.991	0.937	374	312	291	977	54,803	55,267	54,395	374	179	116	19	4.73
11. SR 848	3	0.582	0.660	0.669	78	95	90	263	37,000	35,026	33,456	84	54	45	7	3.00
(Stirling Rd.)	5*	0.448	0.438	0.386	110	96	87	293	41,317	36,092	37,263	104	69	43	13	1.90
12. SR 870	3	1.149	0.991	0.837	479	508	439	1426	51,019	55,480	58,589	684	235	167	40	4.03
(Comer. Bld)	5*	0.937	0.915	0.903	247	261	255	763	53,323	58,484	57,816	335	113	116	18	4.15

TOTALS	3		5931		4059	68%	1153	19%	990	17%	194	3%	
	5		6169		3487	57%	1303	21%	908	15%	193	3%	

Study Segments - Access Class 6 & 7

Roadway Segment	*FROM*	*TO*	*Exception*	*Length*	*Class*
1. SR A1A	*4.136/SR 822-SHERIDAN STREET*	*5.331/CAMBRIDGE STREET-BEACH*		*1.195*	*6*
	2.449/VIRGINIA STREET	*4.041/SR 822-SHERIDAN STREET*	*2.372/WB SR 820-TO-2.725/EB SR 820*	*1.231*	*7**
2. SR A1A	*0.812/EISENHOWER BLVD-OCEAN*	*2.267/HARBOR DRIVE*		*1.455*	*6*
	2.361/HARBOR DRIVE	*2.917/LAS OLAS BLVD*	*2.593-TO-2.696 ONE WAY TURN*	*0.453*	*7**
3. SR A1A	*7.332/WASHINGTON AVE*	*8.422/SE 15 STREET-McNAB ROAD*		*1.090*	*6*
	6.704/HIBISCUS AVE	*7.238/WASHINGTON AVE*		*0.534*	*7*
4. SR A1A	*8.516/SE 15 STREET-McNAB ROAD*	*15.113/SE 10 STREET*		*6.597*	*6*
	15.207/SE 10 STREET	*16.279/PALM BEACH CO LINE*		*1.072*	*7*
5. SR 811 (Wilton Dr.)	*2.386/SR 816-OAKLAND PARK BLVD*	*4.916/CYPRESS CREEK ROAD*		*2.530*	*6*
	0.047/SR 838-SUNRISE BLVD	*2.292/SR 816-OAKLAND PARK BLVD*		*2.245*	*7*

Crash Data Analysis Summary for Access Class 6 & 7 Study Segments (1996, 1997, & 1998 Data)

Roadway Segment	Acce. Class	Safety Ratio			Crash Frequency				ADT			THREE YEAR AVERAGES				Crash Rate (acc./ mvm.)
		1996	1997	1998	1996	1997	1998	TOT	1996	1997	1998	RE	ANG	LT	RT	
1. SR A1A	6	0.644	0.219	0.383	10	4	6	20	9,100	11,500	9,700	7	2	4	0	1.51
	7*	0.583	0.681	0.730	22	27	29	78	20,200	21,500	21,543	17	20	15	2	2.74
2. SR A1A	6	0.790	1.164	0.845	50	70	53	173	37,500	34,000	35,000	74	18	12	2	3.06
	7*	0.705	0.409	0.640	10	5	8	23	24,000	19,857	20,429	13	3	1	0	2.16
3. SR A1A	6	0.384	0.264	0.328	12	10	13	35	20,500	23,260	22,000	12	6	3	2	1.34
	7	0.916	0.678	0.741	16	13	15	44	20,594	21,746	20,880	13	5	3	0	3.57
4. SR A1A	6	1.088	1.052	0.670	81	84	54	219	12,626	13,826	11,751	77	20	40	1	2.38
	7	1.064	0.849	0.459	15	14	7	36	8,920	11,207	10,457	11	3	5	2	3.01
5. SR 811 (Wilton Dr.)	6	2.147	2.247	1.753	136	137	117	390	22,429	21,053	22,932	154	72	70	11	6.36

	7	1.002	1.225	1.959	64	65	107	236	25,000	19,500	19,700	55		61		40		6		4.49
TOTAL	6				837							324	39%	118	14%	129	15%	16	2%	
	7				417							109	26%	92	22%	64	15%	10	2%	

<u>Class 3 vs Class 5 Accident Types - Difference Between Two Proportions Test</u>

Crash Type	Access Class 3	Access Class 5	p	z	SIGNIFICANT (95% Confidence)
Rear End	68%	57%	0.6236	12.4854	YES
Angle	19%	21%	0.2030	2.7343	YES
Left Turn	17%	15%	0.1569	3.0242	YES
Right Turn	3%	3%	0.0320	0.0000	NO

<u>Class 6 vs Class 7 Accident Types - Difference Between Two Proportions Test</u>

Crash Type	Access Class 6	Access Class 7	p	z	SIGNIFICANT (95% Confidence)
Rear End	39%	26%	0.3453	4.5615	YES
Angle	14%	22%	0.1675	3.5745	YES
Left Turn	15%	15%	0.1539	0.0000	NO
Right Turn	2%	2%	0.0207	0.0000	NO

The Wilcoxon Two Sample Test is used to test the significance between Class 3 and Class 5 roadway segment Safety Ratios. The test proved that the Class 5 roadway segment Safety Ratios are significantly higher than the Class 3 roadway segment Safety Ratios. The level of significant is over 99%. Similarly the Accident Rates between the two classes of roadway segment groups are tested using the Wilcoxon Two Sample Test and found to have similar results. The level of significance for the Accident Rate comparison is over 98%.

The proportion of accident types between the two classes of roadways are also tested using the Difference between Two Proportion Test and found to have no significant difference.

Therefore it can be concluded that Access Management is a good Safety Management tool.

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Traffic Safety vs Access Management

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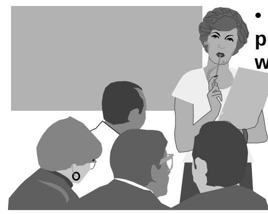
URS

FDOT Access Standards and Intent

- Administrative Rule 14-97: "Standards Rule" adopted February 1991.



- The purpose is to "….protect public safety and general welfare,….."

FDOT Access Management - Arterial Classifications & Standards

CLASS	MEDIANS	CONNECTION		MEDIAN OPENING		SIGNAL
		> 45 mph	< 45 mph	Directional	Full	
GENERALLY DEVELOPING OR UNDEVELOPED AREAS						
2	Restrictive w/ Service Roads	1320'	660'	1320'	2640'	2640'
3	Restrictive	660'	440'	1320'	2640'	2640'
4	Non-Restrictive	660'	440'			2640'
GENERALLY DEVELOPED						
5	Restrictive	440'	245'	660'	2640'/1320'	2640'/1320'
6	Non-Restrictive	440'	245'			1320'
7	Both Median Types	125'		330'	660'	1320'

Qualitative

1. Existing and future functional classification
2. Presence of planned improvements
3. Development density
4. Type of Drainage/edge treatment
5. Existing and future land uses
6. Local street network/frontage roads
7. Potential for access restriction/new median

Quantitative

8. Number of through lanes
9. Posted Speed limit
10. Existing and future traffic volumes
11. Accident history
12. Driveway density
13. Median opening density
14. Signal spacing

Study Purpose

To determine if a correlation exist between Access Classification and Traffic Safety.

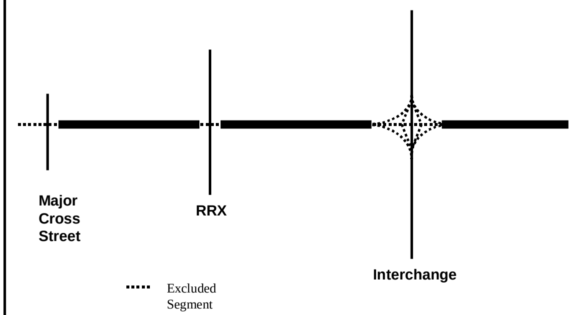
Study Segments - Access Class 3 & 5

Roadway Segment	From	T0	Length	Class
1 SR 5 (US 1)	0.000/DANIA CANAL BRIDGE	2.357/SR 84-SE 24 STREET	2.357	3
	8.381/SR 84-SE 24 STREET	10.235/SR 842-BROWARD BLVD	1.854	5
2. SR 7(US 441)	6.656/ORANGE DRIVE-SW 45 STREET	7.582/SR 862-I 595	0.926	3
	5.184/SR 848-STIRLING ROAD	6.372/ORANGE DRIVE-SW 45 STREET	1.188	5
3. SR 7 (US 441)	20.600/CORAL GATE DRIVE-NW 31 ST	24.402/PALM BEACH COUNTY LINE	3.802	3
	16.297/McNAB-CYPRESS CREEK BRIDGE20.316/CORAL GATE DRIVE-	20.316/CORAL GATE DRIVE-NW 31 ST	4.019	5
4. SR 816 (Oakl Pk.Bld)	0.189/SR 817-UNIVERSITY DRIVE	1.657/INVERRARY BLVD-NW 56 AVE	1.468	3
	1.941/INVERRARY BLVD-NW 56 AVE	3.234/SR 7	1.293	5
5. SR 84 (SE 24th St.)	16.269/E OF SR 7	17.987/SW 15 AVENUE	1.718	3
	18.271/SW 15 AVENUE	19.681/MIAMI ROAD	1.220	5*
6. SR 817 (Univ. Dr.)	0.189/DADE COUNTY LINE-NW215-TPK ENT	9.649/SW 6 STREET	9.460	3
	9.932/SW 6 STREET	20.908/SR 834-SAMPLE ROAD	10.976	5
7. SR 820(Pines Blvd.)	0.189/SR 25-US 27	11.297/SR 817-UNIVERSITY DRIVE	11.108	3
	11.580/SR 817-UNIVERSITY DRIVE	13.902/SR 7-N 60 AVE	2.322	5
8. SR 814(Atlan. Blvd.)	0.189/SR 7-US 441	2.293/SR 849-NW 31AVE	2.104	3
	3.322/SR 849-NW 31AVE	7.775/SR A1A-N OCEAN	3.909	5*
9. SR 834(Sample Rd.)	0.189/SR 817-UNIVERSITY DRIVE	7.427/WB ENT FROM SB SR 9-I 95	7.235	3
	8.032/EB ENT FROM SR 9-I 95	9.396/SR 5-US 1	1.364	5
10. SR 842 (Browd Blvd.)	0.189/SR 817-UNIVERSITY DRIVE	2.950/SR 7	2.761	3
	3.234/SR 7	7.071/SR 5-US 1	3.441	5*
11. SR 848 (Stirling Rd.)	0.189/SR 817-UNIVERSITY DRIVE	2.466/SR 7-N 60 AVE	2.277	3
	2.750/SR 7-N 60 AVE	6.631/SR 5-US 1	3.691	5*
12. SR 870 (Comrcl Bld)	0.189/SR 817-UNIVERSITY DRIVE	6.059/SR 845-POWERLINE ROAD	5.870	3
	6.342/SR 845-POWERLINE ROAD	9.798/SR A1A-OCEAN-NE 50	2.970	5*

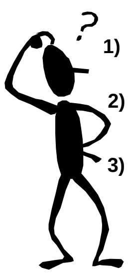
Study Segments - Access Class 6 & 7

Roadway	FROM	TO	Length	Class
1. SR A1A	*4.136/SR 822-SHERIDAN STREET*	*5.331/CAMBRIDGE STREET-BEACH PARK RD*	1.195	6
	2.449/VIRGINIA STREET	*4.041/SR 822-SHERIDAN STREET*	1.231	7*
2. SR A1A	*0.812/EISENHOWERBLVD-OCEAN WORLD*	*2.267/HARBOR DRIVE*	1.455	6
	2.361/HARBOR DRIVE	*2.917/LAS OLAS BLVD*	0.453	7*
3. SR A1A	*7.332/WASHINGTON AVE*	*8.422/SE 15 STREET-McNAB ROAD*	1.090	6
	6.704/HIBISCUS AVE	*7.238/WASHINGTON AVE*	0.534	7
4. SR A1A	8.516/SE 15 STREET-McNAB ROAD	15.113/SE 10 STREET	6.597	6
	15.207/SE 10 STREET	*16.279/PALM BEACH CO LINE*	1.072	7
5. SR 811 (Wilton Dr.)	2.386/SR 816-OAKLAND PARK BLVD	4.916/CYPRESS CREEK ROAD	2.530	6
	0.047/SR 838-SUNRISE BLVD	2.292/SR 816-OAKLAND PARK BLVD	2.245	7

Typical Study Segment



Methods of Comparison

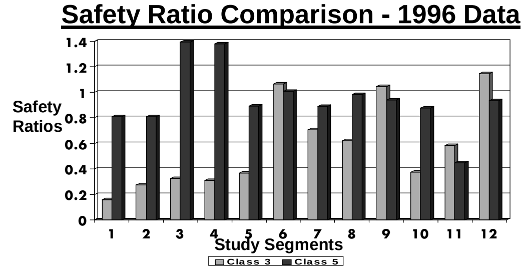


1) Accident Frequency

2) Accident Rate - MVM

3) Safety Ratio = $\frac{\text{Actual Accident Rate}}{\text{Critical Accident Rate}}$

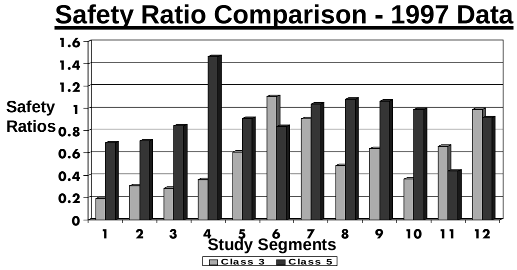
Safety Ratio Comparison - 1996 Data



Wilcoxon's Two Sample Test
w1 = 111 w2= 189 u1= 33 u2= 111
U(0.001) =20 - Accept H, U(0.01) = 31 - Accept H, U(0.025) =37 - Reject H, U(0.05) = 42 - Reject H

Class 3 Roadways have a lower Safety Ratio than Class 5 Roadways *(97.5% significant)*

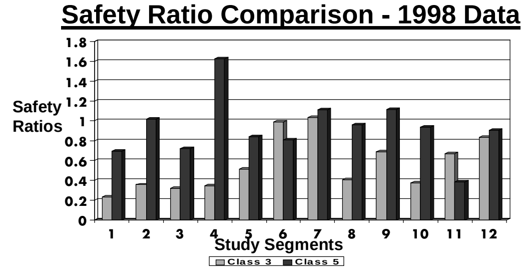
Safety Ratio Comparison - 1997 Data



Wilcoxon's Two Sample Test
w1 = 106 w2= 194 u1= 28 u2= 116
U(0.001) = 20 - Accept H, U(0.01) =31 - Reject H, U(0.025) = 37 - Reject H, U(0.05) = 42 - Reject H

Class 3 Roadways have a lower Safety Ratio than Class 5 Roadways *(99.0% significant)*

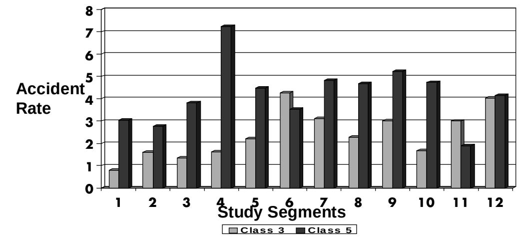
Safety Ratio Comparison - 1998 Data



Wilcoxon's Two Sample Test
w1 = 103 w2= 197 u1= 25 u2= 119
U(0.001) = 20 - Accept H, U(0.01) =31 - Reject H, U(0.025) = 37 - Reject H, U(0.05) = 42 - Reject H

Class 3 Roadways have a lower Safety Ratio than Class 5 Roadways *(99.0% significant)*

Accident Rate Comparison (#Acc./MVM)



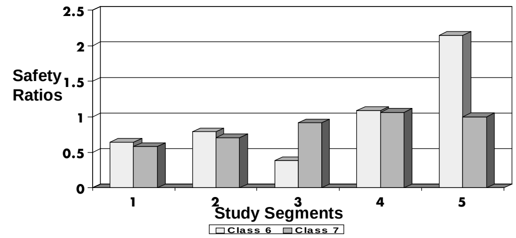
Wilcoxon's Two Sample Test

w1 = 98 w2= 202 u1= 20 u2= 124

U(0.001) = 20 - Accept H, U(0.01) =31 - Reject H, U(0.025) = 37 - Reject H, U(0.05) = 42 - Reject H

Class 3 Roadways have a lower Crash Rates than Class 5 Roadways *(99.9% significant)*

Safety Ratio Comparison - 1996 Data

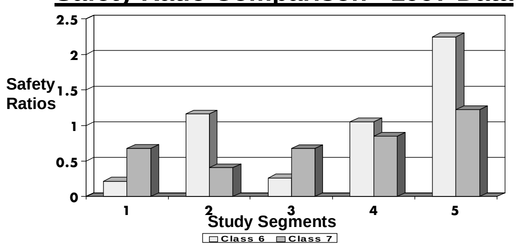


Wilcoxon's Two Sample Test

w1 = 28 w2= 27 u1= 13 u2= 12 U(0.5) = 12 - Reject H

Class 7 Roadways have a lower Safety Ratio than Class 6 Roadways *(50.0% significant)*

Safety Ratio Comparison - 1997 Data

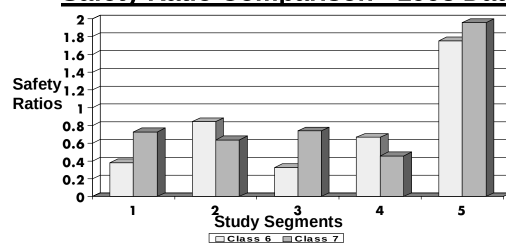


Wilcoxon's Two Sample Test

w1 = 27 w2= 28 u1= 12 u2= 13 U(0.5) = 12 - Reject H

Class 6 Roadways have a lower Safety Ratio than Class 7 Roadways *(50.0% significant)*

Safety Ratio Comparison - 1998 Data

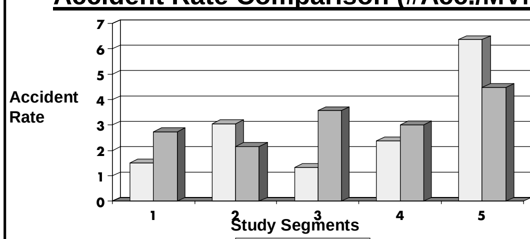


Wilcoxon's Two Sample Test

w1 = 25 w2= 30 u1= 10 u2= 15 U(0.345) = 10 - Reject H

Class 6 Roadways have a lower Safety Ratio than Class 7 Roadways *(65.5% significant)*

Accident Rate Comparison (#Acc./MVM)



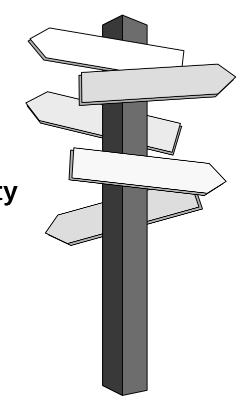
Wilcoxon's Two Sample Test

w1 = 24 w2= 31 u1= 9 u2= 16 U(0.274) = 9 - Reject H

Class 6 Roadways have a lower Crash Rates than Class 7 Roadways *(72.6% significant)*

Conclusion

- **Stricter Access Control leads to better Traffic Safety**



What is Next?

- **Quantify Benefits**

STATISTICAL RELATIONSHIP BETWEEN VEHICULAR CRASHES AND HIGHWAY ACCESS

INTRODUCTION

The Minnesota Department of Transportation has undertaken a variety of new initiatives in an attempt to improve traffic operations and safety on the States 12,000-mile Trunk Highway System. One of the initiatives authorized by the legislature involves developing a process and a set of guidelines to take a more proactive approach to managing access from abutting properties.

In order to inform the legislature of the potential impacts of access management, Mn/DOT has studied the legal issues associated with property rights and local land development regulations. In addition, Mn/DOT retained the services of BRW, Inc. to assist with conducting a traffic safety study to help determine to what extent a case can be made for suggesting that access management is a public safety issue.

Mn/DOT was aware of the potential safety implications of access management as a result of previous research. However interesting this data appeared to be, Mn/DOT did not consider the information conclusive because the reports either did not actually document access density, did not consider different roadway types or the data was based on a very small sample size.

Mn/DOT placed a very high priority on having this study produce credible results with a very high level of statistical reliability. However, during the initial phase of the study it was determined that the data collection efforts associated with a analysis of the entire State Highway system was beyond Mn/DOT's time frame and budget. Therefore the study focused on first identifying and then analyzing a random and statistically representative sample of roadways.

The key steps in the study process are listed below and then described in more detail in the following sections:

- Data Collection
- Document and Analyze Access and Crash Statistics
- Analyze Relationship with Traffic and Roadway Characteristics
- Review Minnesota and Iowa Case Studies
- Conduct Statistical Tests
- Calculate Expected Benefits vs. Costs

In summary, the purpose of this project is to provide a comparison to the results of previous access management research conducted elsewhere and then based on comprehensive analysis of Minnesota access and crash statistics, determine if access management is a legitimate public safety issue.

DATA COLLECTION

Category Selection

The first step in developing this project was to determine the different roadway classifications that would be analyzed for the effect of access on the crash rate. The Minnesota Department of Transportation categorizes its roadways based on five parameters, including, roadway environment (rural, suburban, or urban), roadway design (conventional, expressway, or freeway), number of through lanes, type of median treatment (none or median), type of left turn treatment (none, paint, and physical). Breaking this down, there are 162 possible description combinations for a roadway in the State of Minnesota. Although many of these combinations are not used this was still too large a number of roadway types to analyze and some sort of consolidation was necessary.

The important factor in consolidating the different types of roadways was to come up with a manageable number of homogenous roadway categories that isolate the effects of access characteristics. As a result, eleven different roadway categories were selected for analysis. These roadway categories are listed in Table 1 along with a short definition of the category and an alpha descriptor. The alpha descriptor shown for each category in this table will be used in the rest of this document as an abbreviation for the category definition.

TABLE 1
ROADWAY CATEGORIES

NO.	DESCRIPTION	ABBREVIATION
1	2-Lane Rural Conventional/No Left Turn Lanes	RC2NLT
2	2-Lane Rural Conventional/With Left Turn Lanes	RC2LT
3	4-Lane Rural Conventional	RC4
4	6+Lane Rural Conventional	RC6
5	4-Lane Rural Expressway	RE4
6	2-Lane Urban Conventional/No Left Turn Lanes	UC2NLT
7	2-Lane Urban Conventional/With Left Turn Lanes	UC2LT
8	4-Lane Urban Conventional/No Left Turn Lanes	UC4NLT
9	4-Lane Urban Conventional/With Left Turn Lanes	UC4LT
10	6+Lane Urban Conventional	UC6
11	4-Lane Urban Expressway	UE4

Segment Selection

The definitive study of Mn/DOT's road system would have involved sampling all 4,645 segments and 10,868 miles of conventional roads and expressways in the state. However, this magnitude of data collection was considered beyond the scope of the project and therefore it was determined that a statistically reliable randomly selected sample was sufficient for this project. A preliminary investigation suggested that a minimum total of 500 crashes in each category and a minimum of 25 segments should provide statistically reliable results.

Using the criteria described above a sampling percentage of the total number of segments in each category was determined. This percentage combined with a randomly generated seed applied to the total population of each roadway category then determined the segments that were to be sampled. Table 2 shows the size of the study sample and the statewide population for each of the roadway categories. This table shows that the sample set includes 432 segments and 766 miles of roadway.

TABLE 2
STUDY SAMPLE

	STATEWIDE POPULATION		STUDY SAMPLE	
CATEGORY	SEGMENTS	MILES	SEGMENTS	MILES
RC2NLT	2,710	9,020	120	412
RC2LT	14	20	14	20
RC4	79	142	36	68
RC6	7	7	7	7
RE4	202	577	25	80
UC2NLT	1,166	702	58	38
UC2LT	28	20	20	14
UC4NLT	130	83	48	29
UC4LT	112	83	42	33
UC6	28	26	17	14
TOTAL	4,645	10,868	432	766

Access Data Collection

The most labor intensive and time consuming piece of data to collect was the number of access points in each segment. This information was obtained through viewing the video logs the Minnesota Department of Transportation keeps for all its state highways. The data collection involved scrolling through 766 miles of state highway in order to account for approximately 9500 access points.

The access points were broken down into five different types of access including, public streets, commercial driveways, residential driveways, field entrances and other accesses (access points that could not be identified). The convention that was used for determining the number of accesses involved simply counting the number of intersecting legs with the main roadway. Therefore a T-intersection with the main roadway would constitute one access point and a 4-leg intersection with the main roadway would constitute two access points. It should be noted that the counting of accesses was not affected by whether or not the access point had full access (i.e. open median) or partial access (i.e. closed median).

This counting convention was selected after checking with other researchers at the Federal Highway Administration and Iowa State University. It was determined that this counting convention was consistent with the methodology in other similar research studies.

Crash Data Collection

The crash data used in the analysis of the sample segments was obtained from the Minnesota Statewide Crash Database. The collected data accounted for 13,700 crashes on all the sample segments between the years of 1994 and 1996 and included, total number of crashes, crash rate, total number of crashes for each level of severity (Fatal, Personal Injury A, B, and C, and Property Damage) and categorization of crashes by type of crash.

Segment Data

The segment characteristics for each sample segment were obtained from the Minnesota Roadlog Database. The following segment characteristics were obtained for each individual segment sampled:

- Segment Length (miles)
- Segment ADT (Average Volume across segment from 1994-1996)
- Segment VMT (Vehicle Miles Traveled from 1994-1996)
- Speed Limit
- Segment Environment (Rural, Suburban, Urban)
- Segment Design (Conventional, Expressway, Freeway)
- Number of Through Lanes
- Median Treatment (none or median)
- Left Turn Treatment (none, painted, physical)

TECHNICAL ANALYSIS

The focus of the technical analysis was to document the crash statistics as a function of access density for each segment in each roadway category, identify any observed trends in the data and then to provide an initial assessment of the relationship between access density and crash rate.

Roadway Access Statistics

The statistic used throughout this project to describe the level of access on a segment of roadway is access density. Access density is simply the average number of accesses per mile. It was computed by taking the total number of accesses in each segment that was sampled and dividing by the length of the segment.

It was determined that the average access density for all rural categories is approximately 8 accesses per mile and the average access density for all urban categories is approximately 28 accesses per mile. The data also shows that for similar types of roadway categories the urban category always has a higher average access density than the rural category.

The data also shows that residential driveways (38%) are the most prevalent types of access in rural areas followed by public roads (28%). Public roads (40%) are the most prevalent types of access in urban areas followed by commercial driveways (34%). This data suggests that the greatest opportunities to manage access involve public streets and residential driveways in rural areas and public streets and commercial driveways in urban areas.

Crash Statistics

The statistic used throughout this project to describe the level of crashes on a segment of roadway is the crash rate. Crash rate is simply the number of crashes per million vehicle miles traveled. The number of vehicle miles traveled is calculated from the segment ADT, the segment length, and the period of time over which the crashes were observed.

The average crash rates for the sample segments were first compared with the statewide average crash rates by roadway category. This analysis found that the crash rates for the sample segments are very similar to the crash rates of the statewide population. The data also shows that urban roadways have significantly higher crash rates than rural segments with similar design features.

Additional analysis of the crash data found that there are significantly more single vehicle crashes on rural roadways than on urban roadways and that the percentage of fatal crashes on rural roadways is three times the percentage on urban roadways.

Roadway Access/Crash Rate Relationship

As stated in the introduction, previous research suggests a positive relationship between access density and crash rate. Theoretical reasoning that suggests an increase in crash rate as access density increases supports this premise. This reasoning is based on the belief that turning vehicles and the conflicts caused by these turning vehicles is a major cause of crashes. In addition, this line of reasoning also suggests that with more access points, the number of possible conflict points increase and as a result the crash rate would be expected to increase as well.

The crash rate/roadway access relationship is documented in Table 3 for each of the eleven roadway categories, as a function of the different levels of access density.

This data shows that in almost every category there is a strong positive observed relationship (increasing crash rate as access density increases) between access density and the crash rate. This relationship doesn’t always appear between the different access density groups but it does always exist between the highest and lowest levels of access. Another interesting relationship was noticed when the average access density for each category was compared to these figures. In most cases the access density groups with crash rates lower than the category average also had access densities that were lower than the category average. The reverse was also true as most access density groups with crash rates higher than the category average had access densities higher than the category average.

TABLE 3
SAMPLE SEGMENT CRASH RATES AS A FUNCTION OF ACCESS DENSITY

RURAL ROAD	ACCESS DENSITY (ACCESSES PER MILE)				STATEWIDE AVG. CRASH RATE
CATEGORY	0-5	5-10	10-15	+15	
RC2NLT	0.8	1.0	1.3	1.3	1.1
RC2LT			1.8	2.1	1.9
RC4	0.9	1.1		2.8	1.2
RC6		4.4		2.8	3.4
RE4	0.6		0.8		0.8
URBAN ROAD					
CATEGORY	0-10	10-30	30-50	+50	
UC2NLT	1.7	2.6	4.9	6.0	3.2
UC2LT	3.0	3.0	5.3	5.2	4.3
UC4NLT	2.2	3.3	4.7	7.4	5.3
UC4LT	2.6	4.5	5.6	10.4	4.6
UC6	3.6	4.7	8.7	4.2	6.5
UE4	1.6	2.4		6.0	2.0

Additional technical analysis was also conducted to see if the observed relationship between access density and crash rates could be the result of other variables, such as traffic volume, traffic speed, or related to the type of access (public street, commercial driveway, etc.). To test the effect of traffic volume, crash data was tabulated by traffic volume category. The results of this effort found crash rates to be consistent across each of the volume categories and this suggests that traffic volume does not effect the access density/crash relationship.

In an effort to understand the effect of traffic speed, crash data was tabulated by traffic speed category. Only data for urban roadways was analyzed because there was no variance of speed limits on rural roadways, all of the rural segments had 55 mile per hour limits. The results of this effort shows a strong negative observed relationship between speed limit and crash rate, the crash rate decreased as the speed limit increased.

Analysis was also conducted to determine if the type of access had any effect on crash rates. This analysis consisted of plotting crash rates as a function of the density of particular types of access. The results suggest that in rural areas, the positive observed relationship between access density and crash rate does not appear to be a function of any particular type of access. However, in urban areas it does appear that the observed relationship between access density and crash rate is primarily a function of public street and commercial driveway access.

The results of the technical analysis suggest that a strong positive relationship (crash rate increases with increasing access density) was observed between access density and crash rate.

CASE STUDIES

The technical analyses documented in the previous section focused on the observed relationship between access density and crashes along a sample of Minnesota roadways. This section approaches the safety issues associated with access management from a second perspective, actual before/after case studies for three projects in Minnesota and eight projects in Iowa. The case studies consisted of documenting the following project related information:

- General project description
- Before and after traffic volumes
- Before and after crash frequency
- Before and after crash rates
- Before and after access density (where data was available)
- Results

Minnesota Case Studies

The three roadways included in the Minnesota Case Studies included TH 49 (Rice Street), TH 3 (Robert Street) and TH 61 (Vermillion Street). All of the roadways are in suburbs surrounding the St. Paul-Minneapolis metropolitan area and all were experiencing significant safety problems. These roadways are classified as urban arterials with 30 or 35 mile per hour speed limits and daily traffic volumes ranging from 15,000 to 25,000 vehicles per day. Prior to the implementation of the reconstruction projects, each of the roadways had significantly higher than expected crash frequencies (more than 100 crashes per year) and crash rates (between 6 and 13 crashes per million vehicle miles).

The Minnesota projects, overall, were designed to address the safety deficiencies by reducing conflicts along each of the roadways. These projects include conversion of a two and four-lane undivided roadway to a three-lane road, conversion of a four-lane to a five-lane, and the addition of raised medians with protected turning bays to a four-lane undivided roadway. As a result of these projects, crash frequency and crash rates were reduced by an average of more than 40 percent.

Iowa Case Studies

The Iowa Case Studies were documented in a research report prepared by the Center for Transportation Research and Education at Iowa State University, as part of the Iowa Access Management Awareness Project. The Iowa Department of Transportation, Iowa Highway Research Board and the Federal Highway Administration funded this research project.

The eight roadways in the Iowa Case Studies are located in either the Des Moines metropolitan area or in regional centers around the state. All of the roadways are classified as urban arterials with lower speeds and daily traffic volumes in the range of 15,000 to 29,000 vehicles per day. Each of the roadways is also experiencing high crash frequencies and crash rates (between 5 and 9 crashes per million vehicle miles). The Iowa projects were designed to address the identified safety deficiencies by providing systems of left turn lanes, frontage roads and reducing the number of commercial driveways.

The results of the research from the Iowa Access Management Awareness Project showed that these access management projects had a significant, positive impact in terms of traffic safety. The average reduction in the density of access was approximately 20 percent and the reduction in annual crash rates was approximately 40 percent.

Summary

The crash reductions resulting from all but one of these eleven access management projects are significant at a 95% confidence interval. The only case study where the resulting crash rate reduction was not statistically significant is the Spencer (US 71) case study in Iowa. It is interesting to note that this case had the smallest crash reduction and the highest density of access after reconstruction.

STATISTICAL ANALYSIS

Statistical analysis of the data was a key component of this project to ensure the validity and reliability of the results about the relationship between access density and crashes. Consideration of statistical issues began with the initial random selection process of roadway segments. A randomly generated seed determined which segments would be sampled. This random selection process makes it likely that the samples are representative of the roadways in the state. This increases the probability of producing statistically reliable results.

Following the documentation of the crash rates for each of the roadway categories and the identification of an apparent access density-crash rate relationship, the data was subjected to a series of statistical tests. Within a roadway category, different segments may have different crash rates for a number of different reasons. Conclusions one may reach from a statistical analysis about the access density – crash rate relationship may be suspect unless other effects are found to be unimportant. Therefore, tests were performed to address these concerns.

One reason different sites may have different crash rates could be the dependency of the crash rate on traffic volume. A simple test of the correlation between ADT and Access Density was performed to address this concern. Low correlations were found for nine out of the eleven roadway categories. This indicated that the crash rates were not dependent on traffic volumes.

Another reason why segments within a category may have different crash rates could be because of unobserved differences among the segments. Therefore, a test was performed to check the variability of the observed crash rates within each of the roadway categories. The results indicated that the crash rates varied more than what would be expected (were overdispersed), thus posing problems for statistically reliable results. As a result, specialized statistical analysis was under taken to address the concern of the variability of the crash rates. This analysis would produce statistically reliable results for judging if crash rates tend to increase as access density increases, despite the variability found in the data. The results of this testing showed that, in five out of the six roadway categories that had large enough sample sizes, the crash rate tends to increase as the access density increases (a significant access effect was found).

Confidence intervals (90%) were also reconstructed for the six out of eleven roadway categories that had large sample sizes to produce statistically reliable results. This analysis found that five out of six categories showed a statistically significant difference in crash rates between the lowest access density range and the highest.

Table 4 presents a summary of the access density – crash rate relationship for each roadway category. A positive relationship was observed between access density and the crash rate (crash rate appears to increase as the access density increases) for ten of the eleven segments. Five out of six roadway types with a sufficient sample size to draw statistical conclusions were found to have a statistically significant access effect.

TABLE 4
SUMMARY OF ACCESS DENSITY – CRASH RATE RELATIONSHIP

Roadway Categories	Observed Positive Access/Crash Relationship	Adequate Sample Size for Statistical Analysis	Statistically Significant Access Effect
RC2NLT	✓	✓	✓
RC2LT	✓		
RC4	✓	✓	✓
RC6			
RE4	✓		
UC2NLT	✓	✓	
UC4NLT	✓	✓	✓
UC6	✓		
UC2LT	✓		
UC4LT	✓	✓	✓
UE4	✓	✓	✓

The statistical tests performed show that on a majority of roadway types with a sufficient sample size, there is a statistically significant tendency for sites with higher access densities to have higher crash rates in both urban and rural areas.

BENEFIT-COST ANALYSIS

An analysis was conducted in order to estimate the potential benefits (based solely on crash reduction) that could be realized from the implementation of access management projects.

Benefit-cost analysis looks at the benefits generated by a project and compares them to the cost incurred by the project over a certain analysis period. A project is generally considered economically feasible if the benefits are greater than the costs, producing a benefit-cost ratio greater than one. Typically, the benefits (cost savings) associated with transportation improvement projects may include delay savings, crash cost savings, operating cost savings, routine maintenance cost savings and environmental benefits. This study utilized only the benefits from crash reduction.

The benefits due to crash reduction were determined by first calculating the number of crashes per mile for each category of roadway and then applying an average crash cost using the statewide distribution of crash severity and crash cost values used by Mn/DOT (Property Damage Only = $2,700, Personal Injury = $30,500, Fatality = $500,000). The average annual crash cost per year per mile was then calculated for each category. Finally, values for a range of crash reduction varying from 10 to 80 percent were calculated for each roadway category.

The costs presented for managing access represent initial capital investments annualized over 20 years with a discount rate of 5 percent. Operations and maintenance costs are not included. A range of investment levels and crash reductions were used because it is not possible to determine at this time either the exact cost of an access management project or the exact reduction in crashes that would likely occur due to the level of investment in access management. However, the range of crash reductions (10 to 80 percent) and per mile costs ($100,000 to $2,000,000 per mile) should be sufficient to cover most rural and urban scenarios.

The key conclusion of this analysis is that for many of the assumed combinations of crash reduction and cost per mile for managing access, the benefits outweigh the costs. Crash reduction benefit-cost ratios over 1.0 exist in every roadway category. However, greater benefits for similar levels of investment accrue from crash reduction on urban roadways than or rural roadways:

- If a $500,000 investment was expected to result in a 40 percent reduction in crashes, (the average crash reduction as determined by the case studies), the crash reduction benefit-cost ratios range from 0.18 for a 2-lane rural conventional roadway with no left turn lanes to 3.25 for a 4-lane urban expressway.
- If a $250,000 investment was expected to result in a 40 percent reduction in crashes, the crash reduction benefit-cost ratios range from 0.37 for a 2-lane rural conventional roadway with no left turn lanes to 6.50 for a 4-lane urban expressway.

The results of this analysis have the potential to be used as a guide for assessing the cost effectiveness of different access management projects.

CONCLUSIONS

The previously published safety research has suggested a link between access and crash rates. However, this research either did not actually document access density, did not account for known differences in crash characteristics between various roadway types or the data was based on very small samples. In addition, none of the research used either access or crash statistics from Minnesota.

In order to address these potential deficiencies and to provide an analysis of local crash data, this study was completed, using a representative random sample of segments from Minnesota's State Trunk Highway System. The characteristics of the study sample included 432 roadway segments, 765 miles of roadway (out of a statewide population of approximately 11,000 miles), 9,545 access points and 13,700 crashes (over the three-year period 1994-1996). The roadway segments were then divided into eleven roadway segment categories (five rural and six urban) in order to isolate the potential relationship between crash rates and access density.

Based on the results of the technical analysis, it can be concluded that there is an observed positive relationship between access density and crash rates in ten of the eleven highway categories (i.e., higher levels of access density resulted in higher crash rates). Only the 6-lane category does not show this correlation and this may be due to the small number of segments in this category. Additional analysis of the crash data in each of the roadway categories revealed that in all cases, roadway segments with the highest crash rates have high levels of access density and segments with the lowest crash rates have low levels of access density.

A comprehensive package of statistical testing was performed. The results of this testing indicate that there were sufficient sample sizes in six of the eleven roadway categories to reach statistically reliable conclusions and there was a statistically significant access effect in five of the six categories. The statistical testing also suggests that the differences in crash rates are not related to either traffic volumes or traffic speed.

A Benefit Cost analysis was completed for each of the eleven roadway categories. The results are based on a range of estimated project costs and crash reductions and indicate that positive outcomes (a B/C ratio greater than 1) are possible in every category. However, the data also suggest that urban projects would likely result in greater crash reductions and therefore, greater benefits.

Crash data was analyzed from two different perspectives; a comparison of crash rates on a random sample of the State's Highway System and a Before/After comparison of crash rates from eleven case studies. The results from each approach suggest a strong and statistically sound relationship between levels of accessibility and crash rates.

The final conclusion addresses the key question identified in the Introduction. IS ACCESS MANAGEMENT A LEGITIMATE PUBLIC SAFETY ISSUE? Crash data was analyzed from two different perspectives; a comparison of crash rates on a random sample of the State's Highway System and a Before/After comparison of crash rates from case studies in both Minnesota and Iowa. The results from each approach suggest a strong and statistically sound relationship between levels of accessibility and crash rates. Therefore, the results of the various analyses suggest that yes; access management is a legitimate public safety issue.

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